# RECORDS

OF THE

# GEOLOGICAL SURVEY

OF

# INDIA.

VOL XIII.

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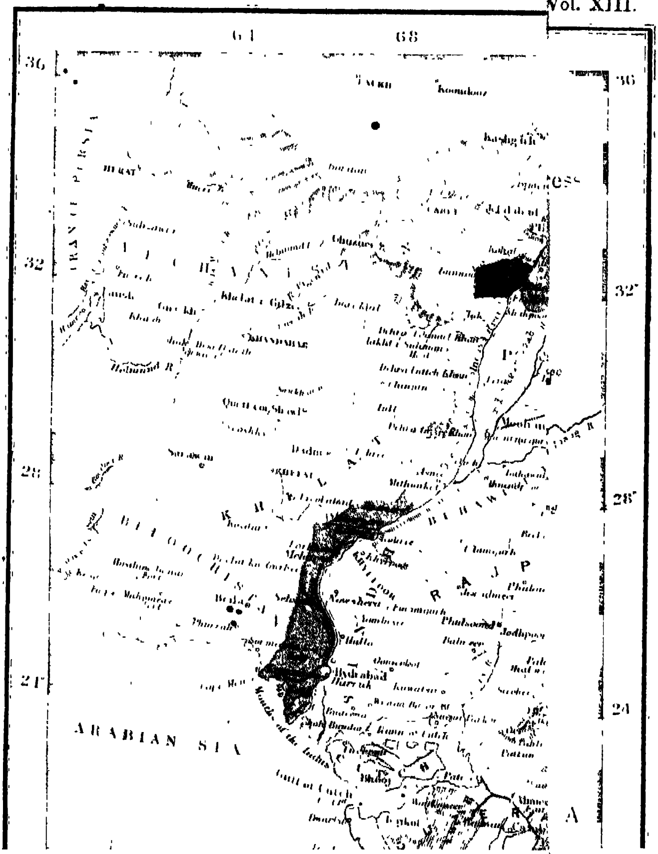
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RECORDS

OF THE

# GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1880. [February.

## Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1879.

In the *Peninsular area* there were five survey parties at work during the field season of 1878-79

S. India.
*Mr. Foote.*

As announced in the annual report for 1878, Mr. Foote took up new ground to the south of Trichinopoly, to trace out in that direction any remnants of the deposits of various ages already known along the coastal region to the north. He carried his work through the Pudukotai State to the latitude of Madura, but nothing of interest was found. The irregular boundary of the gneiss occurs at a distance of about 35 miles from the coast, and the intervening ground is principally occupied by the lateritic formation, overlying and closely connected with the Cuddalore-sandstone group, first described by Mr. H. F. Blanford in the Trichinopoly area. Its exact age is still undetermined—probably older tertiary. The laterite overlaps it to the west, and rests on the gneiss. Mr. Foote's account of this ground is published in the August number of the Records.

Mr. Foote's map and description of the North Arcot district, published in the Records for November, were compiled from observations made many years ago by himself and other members of the Survey.

Godavari:
*Mr. King.*

In the Pranhita-Godavari area, besides the general extension of his survey of all the Gondwána rocks of that basin, Mr. King has fairly succeeded in maintaining a distinction of upper and lower in the Kota-Maleri series, so far as established by overlap, which is still the principal feature of unconformity between the several groups of the Gondwána system. Within the local basin we are indeed still unable, as was shown by Mr. Hughes (Records, XI, page 29), to demarcate the groups closely, but Mr. King has found that to the south there are no representatives of the Maleri clays between the Kota beds and the Sironcha sandstone, which he now recognises as belonging to the Kámthis (lower Gondwánas). The conjectured intercalation of the peculiar fossils of the two zones has not been confirmed, so as to modify this stratigraphical indication; and thus the original distinction indicated by the liassic fossils of the Kota beds and the rhæto-triassic fossils of the Maleri clays stands for the present confirmed. (*See* Pal. Ind., Ser. IV, 2; Manual, p. 151.)

In continuation westwards of Mr. Ball's survey of the Aurunga and Hutár coal-fields (Memoirs, XV, Pt. 1), Mr. Griesbach, during last field season, mapped and described some 900 square miles of Gondwána rocks in Ramkola, between Tatapáni and the Rer river (his Memoir is now at press, as Part II of Vol XV) This ground is the easternmost prolongation of the great central area of South Rewah or the Son, extending westwards to near Katni on the Jabalpur railway, and south-eastwards into the Mahanadi basin, to near Sambalpur.

SON BASIN.
*Mr. Griesbach.*

In the report for last year I gave a brief discussion, based upon Mr Ball's description, of the stratigraphical features of this region as the transition ground between the well-marked divisions of the lower Gondwána series in the Damuda valley and the conditions found in the midland areas, where the higher groups of the lower Gondwánas, as in the Kámthi and Hingir beds, exhibit more the petrological characters of the upper part of the series It seemed as if in the Hutár field and locally in the Aurunga field, we already had this condition established; and I pointed out that we only awaited the discovery of lower Gondwána fossils in the overlying sandstone here to make certain of it, and hence to draw some important inferences regarding the horizon of the top sandstone ("upper Panchet") of the Damuda fields It seems, however, that we shall have to look farther west, within the midland area itself, for the facts of this stratigraphical change. Mr. Griesbach has traced a Raniganj group, with good fossil characters, and a Panchet group less distinctly, at and west of Tatapáni; but these have been reclaimed chiefly from the low-lying outcrops previously supposed to be all of the Barakar group,—not from the hill-forming sandstone, from which the upper (? Panchet) beds are not easily separable. Mr. Ball gave in his map of the Hutár field an indication of the possible position of an intermediate group.

A principal object in sending Mr. Griesbach at once to a typical Gondwána area was, as mentioned in last annual report, that he might elucidate the supposed similarity between these rocks and the Karoo formation of South Africa; indeed this object was of much weight in recommending his appointment to the Survey. In this respect his memoir on the Ramkola coal-fields will be found disappointing, the more so as it shows him to have considerable proficiency in the art of geological surveying. Mr. Griesbach has reserved his observations on this point for a still wider comparison in connection with his more recent work in the Himalayas, of which a notice will be given in the Records for May. He has verbally stated that the Tálchir boulder bed bears a very strong resemblance to the Ecca beds of Natal, and his descriptions exhibit more strongly than any yet given some of the glacial characters of the boulder bed; but he refrains from any expression of opinion on this much-vexed question.

It will be seen that the map of the Ramkola fields exhibits a free use of faults, therein resembling other maps of similar ground. The practice is quite legitimate, faults being a very common feature in such rocks; but it is capable of abuse, and it has often seemed to me that this limit has been passed in our descriptions of these Gondwána basins. A main boundary is represented as a fault, without a word to qualify all the inferences that would follow from the simple use of that word. Thus, as to the throw of this fault, that it amounts at least to the

total thickness of the strata on the downthrow side No *à priori* objection could, indeed, be made on this count, for faults of very great throw are fully established, it is the discrepancy of the fact with other features of the description that calls attention Thus, immediately on the upthrow side of such a fault, or near it, patches of the highest beds of the downthrow series may be seen resting on the base-rock, which fact at once makes the fault in its *primâ facie* aspect impossible When attention is called to this, the usual explanation is, that the fault occurred before that upper group was deposited This assertion is not so easily disposed of, but I consider that in the cases before us it is in a great measure disposed of: it may, I think, be held as impossible that disturbance of such magnitude as is implied by a fault of several thousand feet throw could take place between two groups of a stratified series, and not produce far greater effects of discordance than have as yet been observed between any groups of the Gondwána series I do not forget that I have myself illustrated the compatibility of complete apparent conformity with synchronous great disturbance in the immediate vicinity (Manual, pp 550-51), but that case rather enforces than invalidates the remarks I have just made: if the apparent discrepancy to which I have called attention were susceptible of an analogous interpretation, the notice of the feature as a simple fault would be none the less misleading. I would again invite my colleagues to a more critical attention to their 'faults': an erroneous fault within the stratified series may only lead to mistakes in calculating the position of any particular bed, but a mistake as to the nature of a main boundary leads us altogether astray in judging of the original conditions of the formation, the discovery of which is a principal object of our study Thus, for this Gondwána formation, it is generally supposed to be in the main of subaerial origin, by rain and rivers, and presumably accumulated upon an area of subaerial erosion; yet the ever ready introduction of faults, pure and simple, at the limits of the basins, leaves this supposition out of sight.

KATTYWAR

*Mr. Fedden.*

In Kattywar, which belongs to the peninsular area, on the southern confines of the Arvali metamorphic region, Mr. Fedden completed the survey of some 1,900 square miles (sheets 24, 25, and 36) in continuation to the south of his previous season's work, besides making some preliminary traverses of adjoining ground. With the exception of a small inlier of Upper Gondwána (jurassic) rocks of the Umia horizon near Mewása, and very local outcrops of a sandstone locally underlying the trap, but containing trappean débris, the whole area is occupied by the great eruptive formation. It is mostly stratified, having a slight inclination to the south, but huge dykes traverse it in various directions, forming prominent ridges across the low undulating country. Terraces of the marine miliolitic limestone occur locally halfway up the sides of these ridges. The marble of local repute as Gondal marble is only an irregular sparry vein in the trap, not more than 2½ feet wide; it occurs at Khirsára and Sajriáli, 15 miles north-west of Dhoráji. A cursory visit was made to the famous Junagarh hills, the volcano-like construction of which was early noticed, but which were said to be in part formed of gneissic or granitic rocks. The isolated central hill forming the sacred peak of Girnár is a mass of thoroughly crystalline rock, a granular compound of a clear plagioclase

felspar and a dark-green mineral principally, if not all, biotite, and it seems, indeed, to be the core of a volcanic focus. The annular ridge surrounding Girnár, outside a deep intervening valley, is largely made up of trachytic dykes and bedded basaltic masses with a quaquaversal slope.

RAJPUTANA: *Mr. Hacket.*

In Rajputana Mr. Hacket added a very large area (more than 10,000 square miles) to his previous survey of the Arvali region, extending to the south-west as far as Erinpura. The scattered position of the outcrops in a wide-spread waste of sand makes such a result possible. As soon as the area to the east of the range is filled in, up to the Vindhyan scarp near Búndi, as Mr. Hacket hopes to accomplish during the present field season, a connected account of this portion of the region, up to Delhi, can be published.

The Vindhyan strata were found to cover a large area to north and east of Jodhpur. Their most north-easterly outcrop is at Khátu, 80 miles north-by-east from Sojat. They everywhere rest flatly upon the old rocks—the gneiss, the Raiálo schists, the Maláni felsites, or the Alwar quartzites. There is generally a thin band of fine quartz conglomerate, or of green shales, quite unaltered, at the base, overlaid by pale fine sandstone like the Kaimur rock, to which succeeds a red rock like the Bhánrer sandstone. The whole varies in thickness from 100 feet at Sojat to 350 feet at Khátu. There is sometimes a conglomerate between the two types of sandstone. Cherty calcareous beds are associated with the red sandstone at top, thus connecting this rock with an overlying limestone that covers large areas; it is locally 200 feet in thickness.

A very peculiar boulder formation is described as occurring on and about the Vindhyans, especially the limestone, yet not belonging to them. The blocks, up to 3 feet in diameter, are thoroughly water-worn, formed exclusively, so far as observed, of the Álwar quartzites. They lie loosely, without any matrix, in banks sometimes more than 100 feet thick.

The felsitic eruptive rocks described by Mr. Blanford as the Maláni beds, south of Jodhpur, are considered by Mr. Hacket to belong to the Raiálo horizon, as he found typical beds of that rock associated with the schists north of Dewair, in the centre of the Arvali range.

In the *Extra-Peninsular area* there were two survey parties at work in the cold season of 1878-79; and in the summer of 1879 two were engaged in the high Himalayas.

SUB-HIMALAYA: *Mr. Theobald.*

With the new maps of Kumaun Mr. Theobald surveyed, or at least explored, the belt of tertiary rocks at the base of the mountains between the Ganges and the Káli, in continuation of the work done several years previously to the west of the Ganges. Since these lower hills have been so extensively taken up for forest reserves they have become more inaccessible than ever, the temporary villages and the paths connected with them having disappeared.

The Siwaliks of this region (if indeed the strata of these flanking ridges include true Siwaliks, as Mr. Theobald seems to think) still maintain their character as unfossiliferous, no success having rewarded the search of so

experienced a collector. Other results, too, are wanting, the so far unique occurrence of eruptive rock in the tertiary sandstones at the Gola river (*see* Manual, p 543) remains undescribed. After several consecutive seasons' work upon these sub-Himalayan rocks, Mr. Theobald has now seen more of them than any one else, and he should be in a position to throw some light upon their structure and history. There is no lack of independent speculation in the several progress reports sent in, but there is a too conspicuous want of critical observation, whether in support of the several conflicting views put forward by himself at different times, or in refutation of the interpretations already published by others. After the present season's work, however, we must place on record the result of his more matured study.

SALT-RANGE: *Mr. Wynne.*

In the past field season, or in part of it,—for he also made a reconnaissance of the ground far to the north between Kohat and Thal, on the Kuram,—Mr Wynne accomplished the survey of the western extension of the Salt-range, from the Indus to the outskirts of the Sulimán range, beyond Shekh Budin. Following the great curves of the range, its length is about 100 miles, and considering the great intricacies of the sections, and the peculiar interest of many features of the ground, it will be readily understood that so rapid a survey cannot be very searching, much less exhaustive; but Mr. Wynne's map and description will form a thorough guide to future explorers, the leading features being no doubt pourtrayed with sufficient accuracy. Although the rock-salt, which gives its name to the Salt-range, extends a very short way west of the Indus, all the main structural characters of the western extension correspond with those of the cis-Indus Salt-range, with which Mr. Wynne is so familiar; indeed, without this knowledge the work could not have been accomplished. A principal variation found in this new ground is the expansion of the boulder zone, which near the Indus is the only rock between the Productus-limestone and the Salt-marl. At the south-west end of the Khasor ridge the purple sandstone is again in force, but with an intervening band of red clays, gypsum and dolomite, which alternate with the boulder beds at top. These middle beds are unlike those of similar composition in the saline series, below the purple sandstone, although their general composition would seem to connect them with those lower deposits of the Salt-range series. Mr. Wynne, however, suggests that they may represent the *Obolus* beds, which in the east Salt-range rest on the purple sandstone. Although nearly suppressed in the Maidán-Chicháli part of the range, the Ceratite and Productus-limestone groups are again exposed in force in the Khasor ridge, with very much the same characters as in the western portion of the Salt-range proper.

The jurassic series becomes more developed to the west of the Indus, and a well-defined distinction takes place between an upper calcareous marine zone and a lower one of sandy argillaceous deposits with plant-remains. Mr. Wynne calls attention to the contrast presented in this respect by the jurassic series here and in Rajputana, where the terrestrial (Gondwána) characters occur in the lower division, below the marine limestones, and the series as seen in Cutch, where these characters are found in the upper beds (the Umia zone) above the purely marine deposits.

A cretaceous zone seems to be the least defined of any in the trans-Indus series while the original representative of a neocomian band is described as inseparable from the jurassic deposits, an overlying sandstone of the Chichálí section, at first conjectured to be possibly cretaceous, is described as apparently representative of a rock elsewhere shown to be post-eocene. The treatment of this horizon of the sections, the base of the tertiary series, is perhaps the least conclusive part of Mr. Wynne's work. Altogether his memoir will in this respect prove highly suggestive to future explorers.

By his trip through the very unfrequented ground between Kohát and Thal, of which an account is published in the Records for the year, Mr Wynne was able to complete an unfinished border of the map and description previously given (Records, 1877) of a large area of the north-west Punjab.

In the introductory sketch to his description of the Salt-range fossils, in the Palæontologia Indica, Ser. XIII, fasc 1, Dr. Waagen proposes a very important change in the grouping of the lower deposits of that area Since the discovery of an *Obolus*, by Mr Wynne, in one of the local groups of the series, represented as separated from the overlying Productus-limestone by two intervening groups in which no fossils had been found, although all do not occur together in any one section, it had been received as probable or possible that the Salt-range might contain a more or less partial representation of the palæozoic series, between the silurian, as represented by the *Obolus* beds, and the carboniferous represented by the Productus-limestone. Dr Waagen now proposes to place all the four groups in one connected series, which he calls the Productus-limestone series. Such an arrangement would, of course, be impossible under any literal sense of the terms silurian and carboniferous, as previously applied to the separate groups. It is easy to imagine how the *Obolus* may be disposed of; Dr. Waagen's description of the fossils has not yet got so far; but he has not failed to indicate (*l. c.*, pp 7 and 8) that he considers the deposits to be in succession laterally transitional and vertically associated so as to be inseparable.

SALT RANGE

*Dr. Waagen.*

Dr. Waagen has contributed to the November number of the Records an interesting suggestion regarding the older rocks of the Hazára region. It is based upon some fossils sent to him by the Geological Society of London for description in connexion with the Salt-range fossils. Among them were some in a black slate, they were labelled 'Punjab'; and there is some presumption that they may have come from the Attock slate group, which has as yet yielded no fossils to our search, but which has been provisionally ranked as silurian, partly from an equally uncertain conjecture (*see* Manual, p. 500, note) regarding some fossils found beyond Peshâwar. Dr. Waagen's fossils are of a well marked carboniferous type, and he points out that this age for the Attock slates would at least help to clear up some very puzzling features in the geology of Hazára.

Mr. Lydekker explored a large area of Ladák to the east of his previous observations, and several points of interest have been determined. The gneiss of the Ladák axis, or Kailas range as Mr. Lydekker now calls it (in the Manual local names were preferred until we should know more about what we were discussing), was understood from Dr.

LADÁK:

*Mr. Lydekker.*

Stoliczka's description to be chiefly, if not altogether, formed of altered palæozoic rocks. Mr. Lydekker now shows that the gneissic silurians only occur locally, and that the principal mass must correspond to the 'central' gneiss (or Cambrian gneiss of Mr. Lydekker's previous papers, the identity of which with the 'central' gneiss may perhaps be doubted). The conformity and transition from one to the other is everywhere apparent. The metamorphics of Rupshu are, however, all represented as converted silurians. Thus we should still have to find the gneiss that yielded the blocks in the silurian slates of Pángi, and to explain the sharp unconformity of upper silurian strata on granite and gneiss in Hangrang. (Records, XII, 61.)

A special interest has been noted (Manual, p. 643) as attaching to the great trough of tertiary rocks found along the course of the Indus at the southern base of the gneissic range in Ladák, and crossing obliquely, with the great river, to the north side of this gneiss at a point south of the Pangur lake Mr. Lydekker now shows from good sections that at several points of the boundaries, both with the oldest gneiss on the north and with the carboniferous rocks on the south, the natural original junction is exposed; and this is quite enough to rule the case, though at other points slipping may have been superadded. In several instances the bottom conglomerates of this eocene formation were even observed to show a relation of distribution with reference to the actual gorges of the gneissic range. We may thus henceforth dismiss from our speculations any thought of a former direct connexion of these central Himalayan eocenes with those at the base of the mountains in India, although the similarity of the deposits is so striking. Supposing that the formations of the Zánskár and Kárakoram basins were once continuous across the position of the Ladák axis, it would thus also be proven that a pre-eocene Himalayan elevation took place equal at least to the total thickness of the present sedimentary series from the base of the old gneiss to the top of the cretaceous; for only the unaltered portion of that series this would amount to 16,000 feet, according to Stoliczka's estimate. What the actual elevation of the mountains adjoining the eocene gulph may have been would, of course, depend on how far erosion had kept pace with elevation. The time required for such an erosion must be very great.

Upon the very interesting question of the amount of contortion that accompanied that great pre-eocene elevation, Mr. Lydekker seems to be slightly at variance with his facts, or at least his particular facts, as he duly observes, do not support the opinion he bases upon more general observation. He considers that the contortion of the older rocks took place in great part before that of the tertiaries, because the former exhibit puckerings and crumplings not found in the latter; but in the only contact section given that is not one of original abutting deposition, in the inlier at Miru, the carboniferous and eocene strata are nearly vertical in parallel superposition, so the older must have been flat at the time of deposition of the newer. It is certain that much compression and some crumpling must have attended the depression of the great sedimentary series, when its lower members were converted into gneiss; but it seems to me still an open question whether the great contortions which we now look upon as the special Himalayan disturbance, may not be post-eocene, though, of course, their

lines were determined by the great preceding act of general elevation. (*See* Manual, p 634.)

Mr. Lydekker observes that the extensive exhibition of irruptive rocks connected with the tertiary series is not continuous throughout, and that the masses to the east are different in composition, or at least in texture, from those at the north-western end of the basin. This latter fact may be due to metamorphism accompanying the greater compression in this position, and which has equally affected the tertiary deposits.

NITI
*Mr. Griesbach.*

Mr. Griesbach has accomplished a very successful season's work in the higher Himalaya of Kumaun and Hundes. Compared to Ladák this is a happy hunting ground for the geologist, the rocks being well stocked with fossils, of which a good series has been brought in. Despite the distress of climate and great elevations, Mr. Griesbach has succeeded in mapping the snowy range between the Niti and Milam passes. He is still engaged in working up his materials, and the result cannot fail to be most interesting.

Mr. Blanford was engaged at office during the whole field season, at first for the completion of the Manual and afterwards to prepare his memoir on Western Sind, which had been postponed for some time.

Nothing special occurred to take me from Calcutta, and unless for some urgent duty of short duration, my absence would not be compatible with the steady progress of our work.

*Publications.*—Mr. Wynne's geology of the Salt-range was at last issued early in the year, having lain some fourteen months in type waiting for the colour-printing of the map. It forms itself Vol. XIV of the Memoirs Mr. Foote's memoir (Vol. XVI, pt. I.) on the geology of the eastern coast from latitude 15° to the Kistna was issued in August. Mr. Blanford's geology of Western Sind was issued in December, forming Vol. XVII, pt. I, of the Memoirs. When the work admits of it, memoirs on adjoining areas, or relating to the same geological region, are brought into the same volume; thus, Vol. XV will be completed by Mr. Griesbach's memoir on the Ramkola coal-fields, now in the press: Vol XVI will include Mr. King's memoirs on the east coast in Nellore and in the Godavari district, now preparing for publication; and Vol. XVII will be completed by Mr. Wynne's geology of the Salt-range trans-Indus, now at press.

The Records for 1879 contains 22 papers of various interest, with 11 maps and plates. Two of the articles are by contributors not attached to the Survey: that on Hangrang and Spiti by Colonel McMahon, and that on the old mines at Joga on the Narbada by Mr. G. T. Nicholls of the Civil Service.

Four parts of the Palæontologia Indica were issued during 1879: one by Dr. Feistmantel on the Flora of the Gondwána outliers on the Madras Coast (16 plates), and another by the same author on the Flora of the Talchir-Karharbari beds (27 plates); one by Mr. Lydekker on the Reptilia and Batrachia of the Indian pretertiary formations (6 plates); and the first part of the Salt-range fossils by Dr. Waagen (6 plates). An interruption was occasioned in the publication of Dr. Waagen's work by his receiving in the middle of the year the considerable collection of fossils made in the preceding field-season by Mr. Wynne in

the trans-Indus Salt-range. These had to be cleaned out and arranged with the previous collections before the work of description could proceed. I have already received plates and text in continuation of the work, including some of the specimens sent during the year.

I have great satisfaction in announcing that the description of the Sind fossil corals so generously undertaken for the Palæontologia Indica by Professor Martin Duncan, F.R.S., is very nearly completed. This is the fourth instance of distinguished palæontologists in England giving valuable assistance to the Geological Survey of India by the description of important groups of fossils.

I took an early opportunity, in the annual report for 1877 (Records, Vol. XI, p. 12, 1878), to state the principle of liberty and distributed responsibility under which I proposed to conduct the publications of the Geological Survey, and to explain how the conditions of our work in this country—the great distances to be accounted for and the peculiar difficulties of locomotion—made some such rule necessary to the full performance of our duties to the public. The evident drawback to such practice is the publication of crude work, in which even the competent reader (without any knowledge of the ground) can perceive that more intelligent observation might have given a very different account of the sections. To obviate this objection, the only alternative would be to withhold work from publication until it could be revised in the field by a more thorough observer. Unfortunately, owing to the great scarcity of really accomplished observers, and under the circumstances already noted, this would mean a quite indefinite postponement, and a stoppage of other work. Such had formerly been the practice: in view of further corrections the description of the Rájmahál hills had been withheld for fifteen years, and is at last in quite an unimportant degree better than it would have been at the first; and this is by no means an isolated case. Now, our principal duty is to the greater public, to furnish an intelligible map and description of areas hitherto geologically blank; and our least finished work does that, however imperfectly. The claim of the very select public of competent geologists—that all our work should be up to the best standard of the day—is incompatible with that prior claim, and with the conditions of the situation, subjective, and objective. The points where we fail in this respect do not much affect the value of the work as a guide to the ground. Of course every advice and suggestion is given in each case, so far as can be made from careful perusal of the work in manuscript, but the least intelligent workman is often the last to take advice, and the compelling reasons are mostly such as could only be worked out on the ground. I see no compromise but the one I adopted, and to which I adhere. The risk it obviously implies—the exposure of faulty work—falls upon our own heads. The minor evils it involves are no greater than those it removes, and the smart of public criticism is more wholesome than the heart-burning of official suppression. Correction is, however, seldom more convincing than advice, and in the endeavour to avoid it over-sensitive or under-ballasted writers even run into a worse predicament than that they would escape from. Thus the ball is kept up; the question of official suppression comes round again; as it is impossible that our publications can be made the vehicle of querulous rejoinders. Appeal is then made to non-official censors. Kindly editors of independent journals, quite ignorant of the merits of the case, and too busy to examine it very critically, act

upon the too plausible assumption that an eager protest against superior authority is probably well founded, and so they publish communications which their better judgment might lead them to decline, if only for the sake of the writer himself. I regret that an illustration of this difficulty has occurred during the past year.

*Museum.*—The various collections are in good working order. Two small popular guide books were prepared; one by Mr. Lydekker for our fine series of tertiary vertebrates, and one by Mr. Mallet for the minerals; they are sold for mere cost price at the door, and have met with some demand. Mr. Fedden is now engaged in rearranging the meteorites, amalgamating the Asiatic Society's specimens with the larger collection made by the Survey. Mr. Theobald has prepared a brief account of meteoric phenomena to be prefixed as a popular guide to the new catalogue.

Several small collections of rocks, minerals, and fossils have been forwarded to local Museums and Colleges.

*Library.*—The number of volumes and parts of volumes registered as received during 1879 was 1,283; being 604 by presentation, and 679 by purchase. Arrangements are in progress for the printing of the catalogue.

*Personnel.*—Mr. Ball was absent on furlough for the whole year. Mr. Foote left for two years' furlough on the 13th May. Mr. Mallet took 15 months' leave, on medical certificate, on 25th July. Mr. Blanford took 15 months' furlough from 23rd August. Mr. Hughes returned from furlough on the 15th October, and has taken up work in the South Rewah Gondwána basin on the west, from Katni

I was absent on privilege leave from 26th July to 25th October.

Mr. Richard D. Oldham was appointed by the Secretary of State as an Assistant in the Survey, and joined his post on the 17th of December. He has taken up work with Mr. King in the Godavari valley. In addition to the high proficiency in geological studies evinced by Mr. Oldham at college and afterwards by independent work, we have the pleasure to welcome him as the son of the founder of our Survey and its successful director for a period of 25 years.

Apprentices Kishen Singh and Hira Lall having served their five years of probation with sufficient credit, and having acquired a serviceable knowledge of rocks and minerals, they received, on my recommendation, permanent promotion as sub-assistants. They have been in turn usefully employed in the Office and Museum in the place of the late Assistant Curator, and this post has been in consequence dispensed with. In turns they take the field with one or other of the geologists. It is still, however, very doubtful if they can ever prove competent for independent field-work. Geologist's work may not demand high mental powers, but it inevitably requires some originality of thought in dealing with observation and induction, that peculiarly modern turn of mind to which we owe the present development of natural science, the very quality which more than any other makes the western man different from the eastern. There is little or no gradation of work in geological surveying: to observe and interpret is required from the beginning; and the observation does not consist in measurements, or any kind of manual performance, but virtually to put a life into stones, and to trace the history of that life. Unless this is done with some approach to the standard of modern knowledge the work is not worth paying for.

CALCUTTA,<br>*January* 1880.

H. B. MEDLICOTT,<br>*Supdt. of the Geological Survey of India.*

*List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year* 1879.

BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Sciences.
BOMBAY.—Bombay Branch of the Royal Asiatic Society.
BRESLAU.—Silesian Society of Natural History.
BRISTOL.—Naturalists' Society.
BRUSSELS.—Geographical Society of Belgium.
,, Geological Society of Belgium.
,, Royal Academy of Belgium.
CALCUTTA.—Agricultural and Horticultural Society.
,, Asiatic Society of Bengal.
,, Meteorological Survey.
,, Trustees, Indian Museum.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CAPE TOWN.—Ministerial Department.
CHRISTIANA.—University of Christiana
COPENHAGEN.—Royal Danish Academy.
DRESDEN.—The Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
,, Royal Irish Academy.
EDINBURGH.—Royal Scottish Society of Arts.
,, Royal Society.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Glasgow University.
LAUSANNE.—Vandois Society of Natural Science.
LIVERPOOL.—Geological Society of Liverpool.
,, Literary and Philosophical Society.
LONDON.—British Museum.
,, Geological Society.
,, Iron and Steel Institute.
,, Linnean Society.
,, Museum of Practical Geology.
,, Royal Asiatic Society.
,, Royal Geographical Society.
,, Royal Institution of Great Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
LYONS.—Museum of Natural History.
MADRID.—Geographical Society of Madrid
MANCHESTER.—Geological Society.

MELBOURNE.—Mining Department, Victoria.
„ Royal Society of Victoria.
MOSCOW.—Imperial Academy of Naturalists.
MUNICH.—Royal Bavarian Academy of Sciences.
NEUCHATEL.—Society of Natural Sciences.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
„ Editors of the American Journal of Science.
PARIS.—Geological Society of France.
„ Mining Department.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Society of Natural Science, Tuscany.
ROME.—Geological Commission of Italy.
„ Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
SALEM, MASS.—American Association for the Advancement of Science
SINGAPORE.—Straits Branch of the Royal Asiatic Society.
STOCKHOLM.—Geological Survey of Sweden.
ST. PETERSBURG.—Imperial Academy of Sciences.
SYDNEY.—Royal Society of New South Wales.
TASMANIA.—Royal Society.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
WASHINGTON.—Department of Agriculture, U. S. A.
„ Department of the Interior.
„ Smithsonian Institute.
„ United States Geological and Geographical Survey.
„ U. S. Geological Exploration of the 40th Parallel.
„ Geological Survey of New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.

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*January* 1880.

ADDITIONAL NOTES ON THE GEOLOGY OF THE UPPER GODAVARI BASIN IN THE NEIGHBOURHOOD OF SIRONCHA, *by* WILLIAM KING, B.A., *Deputy Superintendent, Geological Survey of India.*[1]

The last paper[2] written on the geology of this region by my colleague Mr. T. W. H. Hughes, the result, as it was, of later and more extended surveys, placed the relations of the Gondwána strata of this part of the Godavari and Pranhita area in so different a light in some respects to what I had anticipated in my paper[3] of the previous year that it became necessary to revisit the ground over which I had already made a cursory tour with Mr. Hughes.

The result has been to a certain extent satisfactory: a more detailed survey of the rocks has been effected, and some clearer insight obtained of the relations of the different groups of strata; but little additional evidence has been secured as to the conditions of the horizon between the upper and lower divisions of the Gondwána system than what we have ever had in this at first very promising region for the solution of that problem. There is no doubt, however, that we have here near Sironcha two great divisions of the Gondwánas, namely, the Kámthis and an upper series which we have gradually, through Mr. Hughes' researches, come to class as the Kota-Maleris, though I was myself inclined at first to introduce an intermediate group, the Sironcha sandstones, considering it representative of my Golapilli sandstones in the lower Godavari districts.

The main question, and that on which nearly all the others hang, is, as to whether the sandstones of Sironcha town are really of the upper or lower Gondwánas; but unfortunately, after all my endeavours, I have not been able to find fossils or sections which shall absolutely settle this point, though there is plenty of negative evidence on both sides of the question. I should naturally try to employ this negative evidence in favor of my own original view of their relations, but the balance of evidence given by Mr. Hughes seems, on the whole, to be more in favor of a lower Gondwána age for these beds.

The late Superintendent (Dr. Oldham) and Mr. W. T. Blanford are, besides myself, the only members of the Survey who have examined these puzzling beds, and Blanford had already inferred that they are Kámthis. His opinion had naturally great weight with me; but knowing that he had not spent much time over that locality, and that I had already been able to eliminate the upper Gondwánas from his general area of Kámthis at Ellore in the lower Godavari district, while I had up here the remarkable section at Kaleswar, the new facies of the rocks themselves, and the find of plant remains at Anáram, I was led to surmise that there were representatives here also of the lower Godavari rocks. Hughes' paper threw considerable doubt over this suggested correlation, but his

[1] The descriptions in this paper can in great part be followed with the aid of the small map annexed to Mr. Hughes' paper in Vol. XI, Part 1, of the Records. A map of the completed survey will be published with Mr. King's full description in the Memoirs.

[2] Records, Vol. XI, Part 1, 1878.

[3] Records, Vol. X, Part 2, 1877.

boundary between the upper and lower Gondwánas did not satisfy me. I was again extremely puzzled by fresh features in the rocks at Kaleswar, and I find that the Aravi-Somnapali sandstones underlying the Angrezpali outlier of red clays are remarkably like those of Sironcha.

However, on carefully revising my last season's work, I really see no other way to a solution of the question than to yield the point that these sandstones of Sironcha town must be of lower Gondwána age, if not upper Kámthis, then possibly an independent group.

THE SANDSTONES OF SIRONCHA.

For convenience of discussion, it will be as well to write of these still as Sironcha sandstones. I have been led in great part, over and outside of the arguments put forward by Mr. Hughes, to look on these beds as of lower Gondwána age, through having found fossils (decided by Dr. Feistmantel to be preferably of Kámthi age) in rocks of Hughes' ground on the Wardha which from their lithological characters I had at once assumed as representatives of the Sironchas. This was near Porsa, and on a horizon corresponding to that of the Aravi-Somnapali sandstones.

I have unfortunately, with all my search, not been able to find any recognizable fossils at Sironcha, though there are some fragments of stalks on red shales bearing a faint resemblance to others in the Anáram beds. It likewise appears from the following note[1] of the Rev. Mr. Hislop that fossils of lower Gondwána age were once found at Sironcha. "In the sandstone at Sironcha, 6 miles further down the river Pranhita, there is an abundance of compressed stems identical with those at Silewáda: so that there can be no doubt that the argillaceous sandstone there is of the Damuda group. This sandstone of Sironcha is stated by Mr. Wall to underlie almost immediately the Kota limestone."

Looking on the 'Sironchas' as of lower Gondwána age, I can then place the boundary between them and the Kota-Maleris more definitely than was attempted by Hughes: in fact it must run very much where I always drew the line between the Sironcha sandstones and the Maleri clays, or rather the Kotas, for the remarkable feature about the Sironcha sandstones is that they (unlike the other Kámthi or lower Gondwána outcrops to the north-west of Sironcha) are not overlaid by Maleri clays, but by Kota limestones.

From (and including) Sironcha town to the Godavari river opposite Kaleswar there is a tolerably continuous outcrop of sandstones in the left bank of the Pranhita, in which there is not a break allowing of such a boundary as that suggested by Hughes in his map being continued to the Sironcha side of the river. The Sironchas must be considered as at least extending from the north-east suburb of the town to Nagrum opposite Kaleswar. If ever it become necessary to distinguish the Sironchas as upper Kámthis or as an independent group, then their lower boundary must be drawn at Kaleswar, though not at the section on which Hughes and I ultimately agreed that there was only a resemblance of unconformity.

[1] Pro. Geol. Soc., London, 20th November 1861, Vol. XVIII, p. 36.

I have been able this year to trace decisively the beds of Sironcha town across the Pranhita into the rising ground culminating in the hill-station above Arjunguta. We had, I think, always supposed this to be the case, and the hill-station beds had ever seemed to me of a true Kámthi facies, while the ascertained continuity of strata so far carries these beds nearer to the Anáram strata with their upper Gondwána plant remains. The hill-station beds are brown and ferruginous with a decided Kámthi look, and are in part very hard and vitreous, having thus a much older appearance than the Sironchas; however, I actually found unmistakeable Sironcha beds merging into these hard vitreous beds; and so there is no doubt at all, in my mind, that the Arjunguta bed and those of Sironcha are the same; while the former have the Kámthi facies. The Arjunguta hill-station is at the west-south-west end of a line of faults which may be said to limit in part the north-westerly extension of the Sironcha strata, these being also cut off to the south-east, after a length of some 15 miles, by another more or less east-and-west fault near Ardinm on the left bank of the Godavari.

To the north of the Arjunguta hill-station are the oft-noted Anáram beds which yielded the plant remains *Palissya conferta* and *Chirolepis munsteri*, and which I had concluded were overlying the Sironcha beds in natural sequence. The sections and exposures of rock in this part of the country are not continuous, as they are covered up in the most disappointing way by alluvium, and there is the fault just mentioned; still a certain connexion of the Sironcha beds with others in the Kota-Maleri field is apparent, which will always, until fossil evidence be found, cast a shadow of doubt over the grouping and mapping of this series.

As it happens, the Anáram beds are not traceable in the Arjunguta outcrop, but they may be followed down by the right bank of the Pranhita to a point east-north-east of the hill-station, where the outcrop ceases suddenly, there being nothing hence for a mile or so but the high alluvial bank of the river, which bays inland for some distance, lapping round the slopes of the Arjunguta high ground. Not only is there this abrupt ending of the strata, but, after pursuing an even course with a lie of 20° to 30° to the east-north-east, they suddenly show signs of a sharp bend to the south-south-east, with rough slickensides and much silicious and ferruginous infiltration. Nearly all safe signs of lamination and bedding are obliterated in the strong silicious infiltrations which strike irregularly in a general east-north-east to west-south-west run and nearly vertical dip. From this point to the hill-station there is a decided hard wall or ridge of beds much impregnated with silicious and ferruginous matter in the same irregular strips and seams; Anáram pebble beds, purple shales, clays, and sands forming this wall and lying to the north of it.

An important feature about the Anáram locality is, that in going west-south-west from the village, one passes over softish red lilac and buff sands, pebble beds, shales, clays, &c., having a tolerably regular north-east lie; but after about half a mile the beds become troubled, rather flaggy, hard, and more and more ferruginous, when it becomes gradually apparent that one must now be on Kámthis. Such a succession, in descending order, may be found up any of the nalas to the north-west of Anáram as far as Yedlabundun; and thus there seems

little doubt that the Anáram strata are overlying Kámthis, which, though this is partially concealed and interrupted by the fault, are apparently continued in the Arjunguta hill and at Sironcha. No red Maleri clays come in between the Anáram strata and the Kámthis of Linganapeta, but true red clays occur near Isnai, some 5 or 6 miles west-north-west, serially at a much lower horizon than the Anáram beds.

At Yedlabundun everything is covered up for some miles along the valley of the tributary stream, so that neither the Anáram nor the Linganapeta beds are traceable with any certainty to the north-west, though the Anáram beds seem to be continued in the sandstone belt underlying the great zone of limestones striking away to Mulkalapeta, which, as will be seen further on, I take to be the same as the Kota band.

Thus far, the points gained or advanced in this enquiry are—

*First*, that my so-called Sironcha sandstones are of lower Gondwána age and probably belong to the Kámthi group. They are extremely like those of Aravi-Somnapali, which are on a horizon corresponding to that of the beds near Porsa, which Mr. Hughes had already determined as Kámthis, a conclusion verified by the fossils I afterwards found in them.

*Second*, that the Anáram plant shales are locally bottom beds resting on Kámthis, and lower in the Kota-Maleri group than the Kota zone of limestones.

## THE KOTA-MALERI GROUP.

The most definite and recognizable strata in the Kota-Maleri series are the limestone bands. Hitherto, we have been under the impression that there might be only one of these, that of Kota itself, of which the outcrop at Itial (on the Jangaon river) was a portion. I have, this season, been at the trouble of looking up all the outcrops of these rocks, and there is now no doubt at all that there are at least three bands or zones; still the evidence is not quite clear as to the course of the Kota outcrop, that is, it is not continuous over the most important parts of the field. Indeed, the whole limestone sub-division, or what I have previously called the Kota group, is so much broken and interrupted near Sironcha that it will perhaps be better to treat of it separately, as it occurs in two areas, to the north-west and to the south-east of that town.

### *The Pranhita area.*

*The Kota Band* (*No.* 2).—To the north-west of Sironcha there are, first of all, the historic beds of Kota, a mere isolated outcrop in the left bank of the Pranhita. It is to all appearance the same band as that of Tondala to the east of Sironcha, and it appears again to the north-west as the great band, with similar fish scales, at Katapur, whence it stretches away up to near the bank of the Jangaon river at Parwatipet. The line of the Arjunguta fault may strike across between the Kota and Tondala outcrops, so that it is possible they may not be of the same band, though I think they are, being merely stopped for a short distance, but there seems no reason to doubt that the Kota and Katapur outcrops are of one and the same band.

*The Bagarani Band* (*No.* 3).—Towards the Jangaon river and about a mile and half eastward of Parwatipet are some further exposures of limestone in a still higher band, the highest in fact that we know of, but I was not able to detect it to the south-east, except, apparently, spot between Waddaguram and Somtum on the right bank of the Pranhita. This band may also possibly give a doubtful outcrop, noticed last year, as lying below the Chikiala scarps north of Sironcha. No fossils have been seen in this outcrop.

*The Metapali Band* (*No.* 1).—This occurs about 2 miles or less to the west of that of Parwatipet, and is thus lower in the series than the Kota band. It is strongest about Metapali, being there about a mile in width, with a very low dip, and thence it is traceable for a long distance to the south-east past Surarum, Katapali, and Busnai, and for 5 or 6 miles further in that direction. To the north-west I could not follow it satisfactorily, but it appears to run straight for Bibra, a short distance north of which are some outcrops of hard dark-colored limestones. So far this band has failed to yield any fossils. The lie of the beds is, however, so very low, often nearly flat, at its north-east end, that I am almost inclined to think that this band may be represented in the Itial outcrop lying much more to the west-north-west.

The limestones of Itial form, to all appearance, a completely isolated outlier of nearly flat or flat-rolling beds resting on red clays associated with a thick series of sandstones, which in their turn overlie the proper reptilian red clays of Maleri. They are thus for this part of the country the lowest true limestone band in the Kota-Maleri group, and certainly in this way they correspond to the Metapali band, which for its known length is also the lowest band, resting also on a sandstone belt overlying the reptilian clays. The Itial beds are fossiliferous, with lepidotus scales.

Between the thin limestone beds, and above and below them, are great thicknesses of rather soft, open textured variegated sandstones, sometimes having strong runs of buff, pink, lilac and white clay galls and rolled lumps, with which are intercalated thin bands of red and chocolate-colored clays. The limestones shade rapidly downwards into the sandstones by calcareous sands and clays, and intercalated with them also are thin seams of bright red clays. If I am right in my surmise that the Anáram beds are continued north-westward past Yedlabundun, then they lie between the Kota and Metapali bands. This places the *Palissya conferta* and *Chirolepis münsteri* of Anáram with the liassic fish of the limestone or Kota sub-division.

A remarkable feature about the stratigraphy of these limestone bands is, that they are not traceable to the north of the Jangaon river, though two of the sandstone belts associated with them and the red clays are continued on to the Wardha river. Of course this non-appearance of outcrops may be due to the very thick covering deposits of the Jangaon valley; but the probability is, I think, that they have thinned out, and that their flatter lie allowed of greater erosion, only one isolated patch of the lowest band being left.

The lie of the beds is generally very low, from 2° to 3°, though the outcrops are often broad and marked, giving an idea of great thickness. For instance, the most steady and fair outcrop of good massive limestone beds, in the Kota band

near Katapur, cannot be much less than 800 yards wide, which at an average dip of 5° would only give about 200 feet for the thickness. The limestone is usually a grey compact hard splintery rock, rather clayey or earthy, with many seams of white chert; in fact, it appears to have been originally a fine calcareous mud.

The limestone series comes suddenly or decidedly over the Maleri clays by the presence of distinct bands of limestone strata. I could not, however, ascertain in this Pranhita field that this upper member is fairly separable from the Maleri clays except by a sort of overlap, at either end of the field, of the sandstone below the Metapali-Itial band, and that the red clays have their distinctive rubbly calcareous sandstone, just as the upper member has its distinctive bands of limestone. I do not recollect a single instance of rubbly calcareous sandstones in the upper member; but there certainly is a shading of the calcareous elements throughout the group as from distinct river deposits to others of a more estuarine character.

The Metapali-Itial limestones overlie soft variegated sandstones with many thin intercalated beds of red, white, and greenish clays, and a band (or perhaps bands) of dark grey calcareous sandstone, massive and compact, putting on, on weathered surfaces, a guise of limestone so strongly that it must be hammered at to distinguish it from the true rock. Neither is it the rubbly calcareous rock of the red clays. It may be considered as a kind of passage rock deposited in the period of change in the character of the waters of the Kota-Maleri basin This calcareous grit is very constant in the sandstones below the Metapali band, all round (starting from the Itial end) by Rajaram, Sardapur, and Bamena, and so down to Kondampeta. It shows again in force, but somewhat sub-divided, in the thick series of sandstones underlying the Itial limestone and spreading out to the west-north-west up to the Jangaon river from Gungapur.

In following the limestone member to the south-eastward, the Metapali band seems to thin out, though the sandstones above and below it are in force to the tributary nala flowing down towards Yedlabundun. This thinning out may, however, only be apparent, for it is wonderful how these limestone bands are hid beneath the more recent deposits, the débris from the outcrops of the associated sandstone belts being enormously spread over the country.

At any rate, at or near Sironcha, the only band carrying the Kota-Maleris into the Godavari area is that of Tondala, which I take to be of the Kota band, and it is in very close proximity to the Sironcha sandstones.

### *The Godavari area.*

The Kota-Maleris, or perhaps more properly the limestone or Kota member of the group, has been traced out in this direction with somewhat more detail, but there are awkward breaks in continuity of strike, and a very large area to the south of the Indrávati bend of the Godavari is either covered up by superficial deposits, or too shut up by jungle for close survey.

I carried the Tondala outcrop fairly down to Chitur, beyond which village there is no further trace of such rocks until within a couple of miles of

Assaralli; but these beds are shifted out of what would be the course of the band, and very possibly belong to the uppermost Bagaráni zone.

The Tondala outcrop is underlaid by the Sironcha sandstones as far as Chitur, where the latter also end abruptly at an east-west fault, and are succeeded in their strike by two fresh outcrops of limestone. The nearest of these to that of Assaralli is a rather broad and distinct one, running down to Ankissa. This is of the usual Kota stamp, and I take it as corresponding to that outcrop, though no fossils were found in it.

Some 3 miles further west a very strong and rather broad band of limestones occurs close to Ardium, and thence it is continued south-east to the left or north bank of the Godavari. There was no yield of fossils here, but this band must, I think, be looked on as answering to that of Metapali-Itial in the Pranhita area. The feature of this outcrop is, that it is unmistakably faulted against Sironchas, while it rests on sandstones, clays and shales of the Kota-Maleri type.

The great east-west or Indrávati reach of the Godavari presents a blank of new alluvial deposits, but on the right or opposite bank two broad spreads of fossiliferous limestone are again met with which must be continuations of those at Ankissa and Ardium.

The Assaralli outcrop could not be expected to appear, as it must have trended under the Chikiala sandstones of Woraguram. However, to the west of this village, there is a great show of strong beds, for about a mile in width, implying a thickness of 448 feet at least; and in a tumbled outcrop of these I found a fine skeleton of a fish and matted masses of scales. Here also are two thin seams of carbonaceous shale, an accompaniment which adds further to the identification of this as the Kota band. In the broad outcrop of thick-bedded limestones, I obtained a few specimens of fish and saw many others which could not, however, be chiselled from the huge blocks of hard splintery rock. This band could not be followed further south than Palmela owing to the covering gravels and sands.

Three miles further westward there is again a wide belt of limestones having its western edge near Lankalagada, in which a few more fish-remains were found. Here, again, the beds are faulted against sandstones forming the bank of the river, the north-north-east dipping strata being bent down to the southward at the Lankalagada end of the fault. The line of fault is not very clear, but it was more or less east and west, rather to the south of east. The limestones, like those of Ardium, overlie sandstones, which must be considered as of the Kota-Maleri group. The sandstones on the north side of the fault, and forming the bank of the river, are, I think, Kámthis.

This outcrop is traceable south as far as Sigampali, and beyond this only faint traces of limestone occur near Redipali and towards Ahilapuram, where the Kota-Maleri strata trend close on the Kámthis of the ridge south of the village; but there is no section showing the relation of the two groups.

In this southern portion of the field, there are no strata answering exactly to the Maleri member of the group, or the proper Red-clay sub-division; but

it is probable that there is a great thickening out of the sandstones below the Ardium-Lankalagada outcrop.

Certainly there are neither sandstones nor clays answering in any way to the Maleris between the Tondála-Chitur outcrop and the Sironcha beds, though such may have been thrown down by a north-west to south-east fault, else may be hidden under the Tondála beds and deposited against a steep face of Sironcha I could see no trace of a fault along this line, or running from either end into the Maleri country or south-eastwards to Assaralli; hence it would seem as if a natural, though very abrupt, boundary were the simpler interpretation of this unusual association of the Upper and Lower Gondwánas.

But this is an association implying strong unconformity, such as might be expected to occur under the marked overlap pointed out by Mr. Hughes as existing between the Kota-Maleris and Kámthis.

The Ardium limestones overlie a set of sandstones which are very well displayed in the river bank going towards Aipeta. Proceeding up along the river bank, these thick-bedded sandstones are succeeded by a good thickness of variegated beds, and then by irregular bands of greenish-white clays, calcareous sandy clays and shales, and rough rubbly marly-looking bands with recurrent white and light-colored arenaceous beds and other harder seams of sandstone, all having rather a calcareous constitution; and then there are traces of thin chocolate clays coming in towards the top and underneath the limestones. There are also beds of about a foot thick of calcareous grits with small lumps of greenish and red clays.

These are very much the style of rocks overlying the Kota limestones, and, indeed, such as appear here and there, only much less freely exposed, associated above and below all the limestone outcrops; but there are no signs of the bright red-clay series.

Immediately north of the small hamlet of Madagam on the opposite bank of the river, there is a good outcrop of beds like those on the Ardium side; but their ends are faulted against a stronger outcrop of arenaceous beds immediately under the village, in a nearly east-west line. The beds on the north side are much seamed with nearly vertical east-west veins and strings of silicious constitution, the result being that the outcrop is more a series of hard ridges in this direction, giving an appearance of bedding, while close to the fault itself the ends of the strata are turned down to the northward with slickensided faces having a dip of 70°.

In the absence of fossils and any very decided lithological characters, it is, of course, impossible to say that the Madagam beds on the south side are really of a different group or series to those on the north side of the fault; but they certainly appeared to me to have more of a Kámthi facies, and to be the same as the beds further down the river side near Lankalagada.

I have already, in previous progress reports, given an account of the strata underlying the Lankalagada limestone, describing them as of the Kota-Maleri group. They are all sandstones with a few thin bands of red clay, and low down there is a thin calcareous band showing scarcely a fair limestone flag. Now

that I have had an opportunity of examining the Maleri field more closely, I may say that these rocks remind me very much of those underlying the southern portion of the Matapali-Itial limestone band.

Thus far I can write of those southern beds, and the apparent absence or non-existence of any red-clay series; but as the country has not yielded to me any evidence as to the boundary, except that there must be one in the approximate line I have drawn south-eastward from Madapur, I cannot say that the Maleri clays may not be hidden by faulting, or along an old steep shore edge. There is no doubt that the country above this reach of the Godavari is a good deal cut up by dislocation, more generally in the east-west line, and there are indications of steep shore edges.

As bearing on this, however, it may be as well not to leave out of notice a very exceptional occurrence of red and green clays some miles further south, right in the centre of one of the most unfrequented parts of this largest jungle waste in the Nizam's dominions. About 13 miles south of Ahilapuram, while working over an immense succession of ferruginous sandstones which must be reckoned as Kámthis (though I have hitherto always strained at an upper Gondwána place for them, owing to their Sironcha facies) on the Kondaparty stream I suddenly came on high banks of red clays with green and white seams and partings of the well-known Maleri type. I tried all I could to carry this outcrop into some sort of relation with the coarse-brown sandstones in the adjacent jungle, but without success; and I can only now record its occurrence, with the surmise that it is left there in the midst of Kámthi strata by faulting, or possibly as an outlying patch.

Before turning north again to discover more closely the further evidence which has been obtained of the red-clay series, it will be as well again to note the points which have been gained or advanced so far—

1. The Kota-Maleri group may be considered to consist of two members, an upper division characterized by having three well-marked limestone zones, two of which contain fish-remains having liassic affinities, and a lower division characterized by a strong development of red clays with remains of reptiles and fishes of triassic age. This marked difference of age of animal remains in what appears to be one group of a formation is now partly accounted for in the fact that the rocks containing one set are decidedly higher in the group than the rocks containing the other; and as there is still a certain amount of hesitation[1] exhibited by my colleagues in their writings on this single point, I may be excused for reiterating this important feature in the stratigraphy of the Kota-Maleris.

2. In the southern or Godavari area of the Kota-Maleris, the sandstones below the lowest band of limestones have thickened out enormously; and there is no known outcrop answering well to the Maleri clays.

[1] See Mr. Hughes' Rec. Geol. Survey of India, Vol. XI, Part 1, page 25, line 34, *et seq.*, W. T. Blanford, Palæontologia Indica, Ser. IV—2, page 20, line 32, *et seq.* I never considered that the Kota limestone is a band intercalated in the Maleris, though I did agree with Hughes that the two might be of the one group. Again, in the Manual of the Geology of India, page xxiv, line 9, *et seq.*

3. The lower Gondwánas of Sironcha town are succeeded directly by a limestone band of the upper division, either naturally, but abruptly, or less probably by a faulted boundary; but this would only be evidence of unconformity between the lower and upper Gondwánas and not, as I have hitherto supposed, of a break between the two members of the Kota-Maleris.

4. The Anáram sandstones with *Palissya conferta* and *Chirolepis münsteri*, are to all appearance on a horizon between the Kota and Metapali-Itial limestone zones.

One more point of evidence bearing on the relations of the limestone member has been obtained in the Angrezpali patch, which may traverse Mr. Hughes' surmise that the red clays there are on a higher horizon than those of Maleri: for I have found limestones of the Kota type lying just along the southern edge of this patch of clays, on the right bank of the Godavari to the east of Damarakunta, between Malarim and Gondapali. The association is, as usual, not at all clear owing to the covering alluvial deposits of the river; but there is no doubt of the limestone being there associated with sandstones overlying the red clays.

THE MALERI RED CLAYS.

I took up these at the typical exposure on the Wardha river near Porsa, and so carried them southwards, without continuity, but to all appearance and by associated sandstones, towards the Jangaon valley, whence they are more easily followed into the proper Maleri field. The Porsa red clays, however, run under, or to write more correctly, run close up to, and must eventually underlie, sandstones belonging to the belt above the Kota zone of limestones. There is no sign of, nor can there be any room for, the sandstones below that zone, or for the Itial band. There certainly seems to be at this end of the field evidence of a cessation of deposition over the northern frontier of the red-clay basin, which portion was, however, eventually covered up by the later belts of the Kota member (the third sandstone belt, that of Sarwai and Sarsal ridges). This, of course, is virtually only an overlap of these sandstones, not necessarily of the whole limestone sub-division; but there is further evidence yet to come of the possible overlap of the whole sub-division at the Anáram end of the field.

To the south of the Jangaon river, the red-clays show in all their decided outspread; a fair series, displayed more especially about Nambala, Komreli, and Achlapur, of south-eastward dipping red clay bands with intercalations of thin arenaceous beds, and more particularly many bands of grey rubbly calcareous sandstones with indured red, chocolate, and greenish lumps of clay. The reptilian remains must have come from beds in the Maleri field, and not from any higher bands of clay in the upper member, the drainage being all to eastward. The eastern edge of the clay basin runs from a little south of Nangaon past Gungapur, Wodala, Venkatapur, Kasnapali, and Nakalapali to Isnai tank, some 7 miles west-north-west of Anáram. Mr. Hughes, in his small map,[1] carries the western boundary of the clays rather more to the westward than I would have it, but there is certainly a section between Naneala and Rebni showing

[1] Rec., Vol. XI, pt. 1.

that the clays lap over and round brown sandstones and pebble beds (striking north-west to south-east) of unmistakable Kámthi type with ferruginous warts and fungoid segregations. Mr. Hughes' boundary does not run down as far as Isnai, but my having carried it so far is an important point as fetching the lower Gondwána boundary down more to the westward of Anáram with a less easy curve round the Kámthis of Linganapeta.

Along their eastern edge, the red clays suddenly become less persistent, and are succeeded by variegated sandstones with intercalated clay seams, and then by a thick series of thick-bedded sandstones which is perhaps most clearly developed in the fine cliffs, of 60 to 80 feet high, south of Gungapur, and this set of beds may be followed towards Naogaon, or south-eastwards past Akalapali, Kesapur, Sardapur, Bamena, and Kondampeta. The red clays undoubtedly now cease to be the feature, though thinner and thinner seams show as these Gungapur sandstones are followed up; but at the top of them and immediately under the limestones of Itial is a red clay band, next a thin band of limestone, then red clays again, and then the thick zone of limestones. The difficulty is—considering that we have never found any of the Maleri reptilian and fish remains *in situ*—to say from which bed these were derived. The calcareous, or rubbly calcareous sandstone, or even coarse white grit, usually attached to the specimens, would imply that they come from the bands of these rocks in the red clays, and that is at a horizon entirely lower than the Gungapur sandstones: I am also strongly inclined to consider that this is really the case.

From Venkatapur southwards, the Gungapur sandstones, or what I take to be the representatives of them, show above the middle the strong calcareous grit, simulating limestone, already referred to, and I think this seam may be traced down as far as Kondampeta at least; indeed it appeared to me that it runs down even as far south as the parallel of Isnai. West-south-west of Venkatapur, towards Naogaon, &c., I did not find the one calcareous band of grits so clear; there appeared to be more than one band.

The Gungapur sandstones pass along by Naogaon, forming one group with the thick bedded rocks of Aksapur, and I think, those of Chirákúnt, Belgaon, and Balánpur, from all of which Hughes obtained the fossils enumerated in his paper.

Hughes says (*l. c.*, p. 28) of these fossils and the localities—

"In the neighbourhood of Idlara there are the unmistakable red clays with lenticular layers of greyish green granular argillaceous sandstones, and sandstones with clay galls, of the Kota-Maleri group. Thence to the south as far as the range of hills capped by trap, there is no interruption to the series; and at a short distance up the north face of the range and about a mile and a half of Chirákúnt, soft, pale yellow, fossiliferous shales occur that yielded the few species of ferns, cycads, and conifers, &c." "The same plant (*Palissya conferta*) was discovered in 1872 by Mr. Fedden between Móhár and Balánpur, west of Jangaon, in sandstones which I have included as Kota-Maleris." The shales and sandstones near Naogaon (in which I last year discovered *Palissya jabalpurensis* and *Araucarites kachensis*) are also components of the group. They may be higher in the series than the Móhár Balánpur beds, their plant forms sug-

gesting this surmise. I cannot adduce any stratigraphical evidence that bears upon the relationship of the Naogaon and Móhár-Balánpur or Chirákúnt beds, for sections are of the most broken and uninstructive character throughout the whole of the valley of the Jangaon river.

I was not able to visit the Chirákúnt locality, but the whole stratigraphic features seemed to me to indicate that there might be a set of rocks, over the red clays, corresponding to the sandstones of Naogaon, for the lie of both sandstones and underlying red clays is very low or nearly flat over this part of the valley, and the fossils were obtained from a spot a short distance up the side of the hill range. The Móhár and Balanpur fossils were found in sandstones apparently above the red clays; and I have not the smallest doubt but that these rocks answer to those of Naogaon, Aksapur, &c., in fact they belong to the Gungapur sandstones, that is, are above the fossiliferous red clays. Hughes is right about their being in the Kota-Maleri group; but it is highly important that their horizon in this group should be known; and there is this fact certainly, that the Naogaon beds at any rate are Gungapurs, and that the Gungapurs are above the proper red clays.

Having so far made out a little more as to the horizon of the plant beds of the Jangaon valley, it would be a most important gain if they could be placed in accord with the Anáram beds to the south-east. I can, I think, carry the Gungapur sandstone zone down as far as Kondampeta, whence certainly it may have curved round to the east-south-east, and so form the Anáram strata too, thus lapping over the red clays of Isnai on to the Kámthis of Linganapeta. This seems a not untoward lie of the strata, and it is a very tempting position to place them in, as it would give a strong point in favor of the overlap indicated in the Wardha valley; but I cannot satisfy myself on this point. The several bands of sandstone and limestone above the red clays appeard to me to be all running south-east right at the Linganapeta ground. There is, however, a lower lie and a strike round more to the eastward in the rocks about a mile and a half or two miles north of the latter village, and the red clays spread out rather to the south-east of Isnai, so that there may really be a trend round towards Yedlabundun. In the meantime, I prefer to think that the limestone member of the Kota-Maleris does not thin out so easily near Isnai, and that the Anáram beds' position is between the Kota and Itial-Metapali band of limestones.

The point I would now suggest is, that we have here, at the Isnai end of the Maleri field, tolerably present in evidence that the red clays are being well overlapped by higher and higher strata of the limestone member between Isnai and Anáram.

For the whole field of Kota-Maleris, the various points gained or suggested may be summarized thus—

The series appears fairly separable into two groups, the Maleris and the Kotas, which have already been referred to in this paper as the Red-clay and Limestone members. The Red-clay or Maleri sub-group is overlapped at its northern end, between the Jangaon and Wardha rivers, by an upper sandstone zone of the limestone or Kota sub-group; and even before the doubtful boundary between the sandstones of Sironcha and the Kota limestone is reached to the

southward the same clays are again overlapped by the Anáram strata while they do not appear to be represented in the southern or Godavari portion of the field.

This separation by overlap accords in some measure with what is known of the animal remains found in either.

The position of the plant-remains is less clear, but that of the Naogaon and Anáram, and perhaps of the Balánpur fossils is above the red-clays, there being overlap in the Anáram case. The plant-shales are in sandstones which run with the red clays up the Jangaon valley, but this, the Gungapur band of arenaceous strata, does not appear to be represented on the Wardha river, the clays there being overlaid by strata to all appearance higher than the Kota zone of limestone; hence we may infer that the Gungapur beds are not co-extensive with the clay series at the northern end, while they overlap it at the other end of the field. On either view of the horizon of the Anáram plant-shales, either as a thinned-out end of the Gungapur beds, or as of the arenaceous zone between the Itial and Kota limestones, their position is still above the clays. I have endeavoured to explain the positions of the Chirákúnt shales as being also above the clays.

The great difficulty lies in saying where the Maleris are to be considered as ending, and where the Kotas begin. I am fairly at a loss in the proper Maleri field itself, for there are no known sections giving the relations of the two subdivisions. I think the Kotas must be considered as commencing with the Gungapur sandstones even though there be so many thin seams of red clay in that set of rocks as well as up into the limestone zones. The Gungapur beds are thick, and in their constitution they point, on the whole, to a kind of deposition totally different to that of the red clay series, after which a great change must have taken place in the drainage system of the country bordering the Maleri basin; while the successive overlapping of the succeeding deposits on the clays at the northern end of the field indicates a long period of unrepresented time during which the change in animal life might have taken place.

I would then only modify Mr. Hughes' latest classification of the upper Gondwánas so far as to break up his Kota-Maleris into two of the groups proposed in my original provisional list, which are themselves also modified, inasmuch as the Anáram beds are now ranged in the Kota group instead of with the Sironcha sandstones.

### Chikiala Sandstones.

These were followed out to their bounds in this area, but without giving any more evidence as to their relations with the Kotas. However, until more is known of them, it will be better to leave my old correlation of them with the Tripati sandstones of the lower Godavari Upper Gondwánas as a very open question. In some respects they are even like the much newer and tertiary Rájáhmandri sandstones of that region. My arguments as to the age of the Balánpur beds will show that I do not think they are at all recognizable by position as Chikialas.

GEOLOGY OF LADAK AND NEIGHBOURING DISTRICTS, BEING FOURTH NOTICE OF GEOLOGY OF KASHMÍR AND NEIGHBOURING TERRITORIES, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

(WITH A MAP).

INTRODUCTION.

The portion of the Himalaya geologically examined by myself during the past summer comprises the country on and adjoining the main road from Kashmír to Leh, a considerable portion of Drás, Zánskár, and Ladák; the regions about the Pangong Lake and Cháng-Chenmo, and a part of Rupsu and Kulu.

A considerable portion of this area has been already traversed by the late Dr. Stoliczka, and the serial position of most of the rock-groups occurring therein approximately determined.[1] Dr. Stoliczka's survey was, however, mainly confined to the high-roads, while my own embraces a large extent of the surrounding country. I am, therefore, able to present a fairly complete general map of the greater part of the districts in question, in place of the isolated rock-groups colored in by Dr. Stoliczka. My own more extended observations have also led to certain modifications of the views entertained by Dr. Stoliczka as to the relative ages of some of the rocks in these regions, but on the main I agree with the conclusions arrived at by our former colleague. I may also add that I am indebted to Dr. Stoliczka's notes for some of the boundaries shown on the map.

In my previous papers on the geology of the Kashmír Himalaya,[2] I have generally treated the subject in the manner of an itinerary; describing the different rocks as they occurred on my various routes. This method of treatment, however, would not be suitable to the present area, and I, therefore, propose to treat of each group of rocks by itself.

In geologically mapping an area which consists in the main of exceedingly lofty mountains and elevated valleys, it is of course impossible from the nature of the ground, to be always perfectly accurate in tracing continuously the boundaries of the various rock-groups; not unfrequently, therefore, in my map when such boundaries are far removed from the roads, they must be considered merely as more or less accurate approximations connecting the fixed points where the boundaries cross or approximate to the practicable roads, or accessible regions.

I shall divide my subject into four main headings, *viz.* (1), the older Palæozoics of Drás and Ladák, (2), the rocks north of Cháng-Chenmo, (3), the rocks of the Zánskár and Ladák basin, and (4), the rocks of Lahúl and Kulu, while in a fifth section I shall make some more general remarks on the relations of the rocks of the whole area.

I once again have to deplore the absence of any trace of fossils in the older Palæozoics of the region surveyed, which absence precludes any minute sub-

[1] Mem. Geol. Surv. India, Vol. V, pp. 182, 337. Scientific results of Second Yarkand Mission: Geology.

[2] Rec. Geol. Surv. India, Vols IX, XI, XII.

divisions or correlations of the rock-groups, and which also renders the interpretations of their age open to a certain amount of doubt.

In mentioning the names of places in Ladák, I have generally made use of the Tibetan name "Lá" for a pass and "Tso" for a lake; thus, "Kangi Lá" for "Kangi Pass," and "Tso Moriri" for Moriri Lake. This avoids such barbarous repetitions as Kangi *Lá Pass* and *Tso* Moriri *Lake*, which one sometimes meets with.

With regard to the propriety of applying the names of the European rock series to the rocks of the Himalaya, in cases where no fossil evidence is available, it appears to me that, since we have in the Himalaya some of the rock-groups clearly indicated as being the homotaxial equivalents of European rocks-groups, it is simpler to apply provisionally to the rocks underlying and overlying such known horizons, the same names as are applied to the similarly placed rocks of Europe. I wish, however, at the same time, as I have observed elsewhere, to impress on the reader most distinctly that I do not for one moment consider that any of the Himalayan rocks are exactly equivalent, either in thickness or in time of deposition, with the correlated European rocks; but that I merely indicate that the rock sequence in the two regions generally follows the same order. It would be equally easy for me to invent new terms for each and every Himalayan rock-group; but it appears to me that when my meaning can be equally well conveyed by the use (in a wide sense) of well-known and well established terms, that it is far preferable to employ such terms than to add to the list of new and little-known ones, which already cumber the paths of science to such an appalling extent.

## I.—Older Palæozoics of Drás and Ladák.

In my last published paper on Himalayan Geology,[1] I have stated that the jaspideous, trappoid and slaty rocks occurring in the neighbourhood of Drás, are found, if traced to the westward into the valley of the Kishenganga, to underlie the limestones of the Carbo-Triassic series, and also to correspond in mineralogical composition to the rocks of the Pír Panjál. It may, therefore, be assumed that both the Drás and Pír Panjál rocks are of pre-carboniferous age, and that they in all probability roughly approximate to the Silurian.[2]

Taking now the Drás Silurian rocks as our starting point, and proceeding in a north-easterly direction along the Ladák road, we shall find that these same

[1] Rec. Geol. Surv. India, Vol. XII, p. 20.

[2] This conclusion will be confirmed in the sequel. Dr. Stoliczka (Geology of 2nd Yarkand Mission, p. 12) compares these Drás rocks to the trappoid rocks of Srinagar, and considers them as certainly the same; from page 16 of the same work we learn that Stoliczka considered the Srinagar rocks, like similar rocks in Cháng-Chenmo, as Silurian. In a former paper (Mem. Geol. Surv., India, Vol. V, p. 349), he considered part of the Drás rocks as Carboniferous.

In the first of these two papers, Stoliczka appears to have considered that the slaty rocks of Drás underlay the Trias dolomites of the Drás river and Mataian, while in his last notes he appears to have considered (as I do) the junction a faulted one; this would account for the two ages assigned to the Drás slaty rocks. In classing them all as Silurian, Dr. Stoliczka's last conclusions agree with my own. In these last notes he also considers the Trias nearest the Drás slates as the newer (Para), whereas in the first paper he classed it as the older (Lilang).

slates and other rocks are continued about as far as the village of Dandál. In this district, these rocks are frequently jaspideous like those on the road from Drás to Tilel (Tilail) described in my above-quoted paper, and they often acquire a black "river-glazing," while they disintegrate into a dark and heavy iron-sand. Occasional beds of the true slates are highly ferruginous and weather to a rusty-red color: there also sometimes occur thin beds of a coarse conglomerate resembling that found among the slates of the Pír Panjál, the occurrence of which confirms the identity of the rocks of the two districts: near Drás the rock is like some of the trappoid rocks of Kashmír.

Still following the course of the Drás river, we find, below Dandál, the rocks gradually assuming a hornblendic character, and not unfrequently containing crystals of pure hornblende of a large size. Near the halting place of Tashgám, the strata are thrown into several small anticlinals, the lowest exposed beds consisting of a dark-colored syenitic gneiss,[1] while the higher beds consist of the Drás slaty rocks: from the latter to the former, there is a complete and imperceptible passage through the above-mentioned hornblendic rocks, so that I come to the conclusion that the lower part of the slate-series has here been altered into gneiss.

From Tashgám to near the junction of the Drás with the Shingo-Shigar river we have alternations of small gneiss anticlinals overlaid by slaty rocks Some of the latter closely resemble in their mineralogical characters the massive bluish rocks of the Panjál series, which occur at and near Shísha-Nág in Kashmír,[2] while others are like the ferruginous slate rocks of Drás.

Near the junction of the two rivers mentioned above, we come upon a massive light-colored syenitic gneiss (syenitoidite) which seems to underlie conformably the transition rocks.

Another ridge of the same (generally syenitic) gneiss occurs immediately to the north of Drás, apparently underlying the slates of Drás on the one side, and the transitional rocks of Tashgám on the other. I have not traced these rocks far to the north-west of the Ladak road, but I have already mentioned[3] that gneiss pebbles occur in the Búrzil river on the Kashmír and Astor road; and General Cunningham[4] also states that the table-land of Deosai or Deotsu (to the north-west of my map), consists principally of granite, by which he doubtless means the same gneiss: there is, therefore, every probability that a continuous band of these crystallines extends to the north-west of Drás and Kargil. The eastward extension of this Deosai and Drás gneiss will be described below.

The gneiss anticlinals near Tashgám are probably the highest beds of the main gneiss ridges, and are frequently dark colored; but as the main mass of the rocks between the two ridges of gneiss are the same as the slates of Drás, they have been colored of the same tint in the map. We shall, however, subsequently

[1] The whole of the north-western Himalayan gneiss which I have seen, whether hornblendic or micaceous, is granitic in structure, and never distinctly foliated. The hornblendic variety may be termed "syenitoidite," and the micaceous "granitoidite."

[2] Rec. Geol. Surv. India, Vol. XI, p. 44.

[3] Rec. Geol. Surv. India, Vol. XII, p. 24.

[4] "Ladák," p. 57.

see that in Ladák portions of the slate series are sometimes locally altered into a dark-colored gneiss which overlies the massive lighter-colored gneiss, and the same may not improbably be the case with the Tashgám rocks.

To the eastward of Drás, the slaty rocks may be traced across the Suru river as far as a line running nearly from north-west to south-east through Múlhetrúng Station, where the rocks of the great Triassic series appear to be faulted against them. To the south and south-east the same slates overlie the gneiss of Suru and Rúndúm, and were identified by Dr. Stoliczka as undoubted Silurians. If, as I infer from Dr. Stoliczka's notes, the gneiss of Suru is overlaid conformably by the slates, the former may probably be the same as the gneiss of Drás and the Shingo-Shigar river: this question will be discussed more fully in the sequel. The Suru Silurian slates have been traced by Dr. Stoliczka in a band running south-south-east from Rúndúm to the south of Zánskár, and are there continuous with those of North Lahúl and Spiti, which will be referred to again in the third section of this paper.

Returning to the main axis of gneiss to the north of Tashgám, I proceed to trace its eastward extension, and to consider its relations to other rocks to the east. From the junction of the Drás with the Shingo-Shigar river, the gneiss extends to the south-east as far as Kargil and Chattu, where it is overlaid by the Tertiary series. From Kargil I have traced the gneiss down the Suru and Drás rivers as far as the Indus, but did not reach its northern limit. The gneiss in this district is sometimes fine-grained and dark-colored, and at other times coarse-grained and light-colored. At Kargil a very massive light-colored gneiss, without any trace of stratification, underlies the darker and more distinctly stratified upper gneiss.

From Kargil the southern boundary of the crystalline series runs in a generally south-easterly direction.[1] It keeps to the south of the Indus till near the village of Dorgu, when it crosses to the northern bank. To the eastward of Dorgu the boundary forms a sinuous line along the bed of the Indus for some miles; it then runs at some distance to the north of the river, passing close to the villages of Skining, Pharka, Himis, and Ling: from the last-named place the boundary bears to the south-east, till it again joins the Indus at Pittak, south of Leh. To the south-east of Pittak the southern boundary of the crystallines follows approximately the course of the Indus, generally running somewhat to the north, and has been traced as far as a point due south of the Pangúr Lake.

It now remains to say something of the composition, and relations to other rocks, of the Ladák crystallines.

To the south-east of Kargil along the Indus valley the gneiss usually consists of the light-colored massive variety, and has generally a north-easterly dip, so that the older beds appear along the valley of the Indus and the newer towards the top of the Kailás range.

The composition of the rock varies considerably; in most cases, indeed, the

[1] The range on the right bank of the Indus in Ladák has been termed by General Cunningham ("Ladak," p. 48) the "Kailás range," a name which I adopt here: in the "Manual of the Geology of India" this range is called the "Ladák range.". This range forms a dominant branch of the range north of the Manasarowar Lake.

rock is a true syenitic gneiss, consisting of quartz felspar and hornblende. This is, however, not always the case, since I have already shown[1] that the gneiss of Drás has a true granitic composition, consisting of quartz, felspar, and two kinds of mica. Near the village of Himis, to the west of Leh, I collected the following varieties of crystalline rocks,[2] *viz.*—

| | | |
|---|---|---|
| Gneiss. | Mica in small flakes. | (Granitoidite.) |
| Syenitic gneiss: | *a.* Pink orthoclase. | (Syenitoidite.) |
| | *b.* White do. | |
| Pegmatitic gneiss. | (Pegmatoidite.) | |
| Hornblende rock | *a.* Small crystals of Hornblende. | |
| | *b.* Large ditto. | |

The hornblende rock usually occurs in small irregular patches.

At Tánkse, 40 miles to the east of Leh, the greater portion of the gneiss is porphyritic, containing numerous crystals of white orthoclase; near Shushál, 45 miles to the south-east, the orthoclase is pink colored. In the Chimray valley, on the Leh and Tánkse road, the gneiss is traversed in all directions by veins of an intrusive rock, agreeing with some specimens of the albite granite of Dr. Stoliczka. This granite is very light-colored, and consists of quartz, albite felspar, and black mica: the latter occurs in large flakes, and not unfrequently forms a thin coating to quartz crystals of very large size. This albite-granite intrusion is very characteristic of the central gneiss.[3]

With regard to the relations of the Ladák gneiss to other rocks, the most clear sections are displayed near Tánkse and the Pangong lake, and I accordingly commence with those districts. At Tánkse itself we find the crystalline rock to be a massive white, and generally porphyritic, syenitic-gneiss, the higher beds consisting frequently of alternations of dark and light bands. To the south-east of the village of Chilam, near Tánkse, this porphyritic gneiss is distinctly seen to be overlaid by white and greenish quartzitic sandstones, black and green slates, banded jaspideous rocks, a few conglomerates, and the peculiar massive half-slaty half-sandy rock, so characteristic of the Silurians of the Drás river. The whole of the slaty series, both in structure and in position, exactly resembles the slate series of Drás, and there seems to me but little doubt that they are one and the same series. This slate series forms a long narrow ellipse extending from near Tayár, in a south-easterly direction, to a point south of the Pangúr lake. The centre of this ellipse shows here and there a central core of white non-porphyritic gneiss underlying the slates, and forming the highest peaks of the range.

In the Chilam valley the northern boundary of this ellipse appears to be a faulted one, as on the north side of that valley we have hills of gneiss with a northerly dip, while to the south there are dark slates underlaid by gneiss (at the base of valley) with a southerly dip; this fault is apparently continued far

[1] Rec. Geol. Surv. India, Vol. XII, p. 19.

[2] In his last notes (Geology of 2nd Yarkand Expedition, p. 16), Dr. Stoliczka mentions the varied composition of the Ladák gneiss, which he had previously described as syenitic.

[3] Stol: Mem. Geol. Surv. India, Vol. V, p. 18.
Mc'Mahon: Rec. Geol. Surv. India, Vol. X, p. 221.

to the south-east. To the north-west of Tánkse, the fault, on the other hand, seems to have died out, and the slates appear to rest conformably in a regular synclinal of the gneiss. Taking a transverse section to the south-west from Tánkse *viâ* the Käi Lá, we find to the east of Käi Tso the slate series with a north-easterly dip, underlaid conformably by the white non-porphyritic gneiss of the Indus valley. This gneiss, especially in its higher beds, contains not unfrequently bands of a darker color, as we found to be the case at Tánkse.

Some of the slates, in the middle of the series, between Tánkse and the Käi Lá have been locally altered into a fine-grained, dark-colored, and generally imperfectly crystallized gneiss, quite distinct in character from the underlying white gneiss. Further to the north-west on the road between Tánkse and the Chang Lá, the upper dark gneiss, altered out of the slates, is seen resting on and passing down into the white gneiss of Tánkse. This section, therefore, establishes the important fact that there exists in Ladák gneiss of two distinct ages...one altered out of Silurian slates, and another underlying such slates, but apparently also, at all events partly, altered out of an older conformable series. This fact may lead, as mentioned, to the inference that the darker colored and higher gneiss of Kargil, already referred to, may really very possibly be the altered Silurians, though, as before said, the question cannot at present be definitely settled.

As already stated, the white gneiss of the Indus valley dips generally to the north-east, and the higher beds consequently form the summit of the Kailás range. Along the greater part of the Indus valley in Ladák the white gneiss continues to the crest of the range, but near Leh itself, below the Khárdong Lá[1] and Láswan Lá, we find the white syenitic gneiss overlaid by alternating bands of dark and light-colored gneiss like the higher gneiss of Tánkse and the Käi Lá. This striped gneiss is again succeeded by an imperfectly crystalline, dark-colored, and fine-grained gneiss, alternating with partially altered slaty rocks, and occasional unaltered slates. These rocks appear to occupy a synclinal ellipse in the white gneiss, the boundaries of which are approximately indicated on the map. From the nature and position of these rocks, I have little doubt but that they are the altered equivalents of the slates to the south of Tánkse, and they have been colored accordingly in the map; this is, however, only a conjectural correlation.

To the northward of Leh, the crystalline series has been traced by Dr. Bellew along the Shahidúla and Yarkand road as far as Sá-Sango where it appears to be succeeded by Silurian slates.

Returning once again to the Tánkse district, we find that the range to the south-east of Tánkse, running parallel to the north-western half of the Pangong lake, consists of the porphyritic gneiss of Tánkse. This gneiss I have traced some distance to the south-east of Shushál, where it is overlaid by Silurian slates, connecting those to the south of Tánkse with those of the Pangong lake, which will be referred to immediately. On the northern flank of the

[1] This pass is called on the Topographical Survey maps the Laowchi Lá, though it is always spoken of by the natives as the Khárdong Lá.

Tánkse range, to the north-east of Tánkse, we have a regular ascending series of gneissic rocks. The higher beds become gradually interstratified with unaltered slates and sandstones, with some banded jaspideous rocks; till finally all gneiss disappears, and the series consists solely of slaty and sandstone rocks, corresponding exactly in mineralogical character with the slaty series to the south of Tánkse. The transition from the crystalline to the slate series is, however, here so very gradual that only an arbitrary boundary can be drawn, but the higher gneissic rocks are probably altered Silurians.

The slaty series I have traced to the north-west to the Shyok river, and to the south-east, along the whole length of the Pangong and Pangúr lakes: its north-eastern boundary I shall refer to subsequently. Near Bapi Station to the south-east of the Pangúr lake, the slates are underlaid by a core of granitoid gneiss. We have already seen that to the north-east of Tánkse there is a regular sequence from the crystalline to the slate series; along the south-western shore of the Pangong lake, on the other hand, the junction between the two series seems to be a faulted one, the black slates and green shales and sandstones which form a narrow band along this shore of the lake dipping towards the gneiss. Still further to the south-east the junction again appears to be a normal one. In the mineralogical composition of the rocks surrounding the Pangong lake, there is very great variety, but with one exception they consist mainly of colored slates, shales and sandstones. I have already mentioned the composition of these rocks on the south-western shore of the lake, and need not, therefore, refer to them again. On the opposite shore, in addition to the rocks of the south-western shore, there also occur banded jaspideous rocks, together with the slaty-sandy rock of the Drás river, and true slates which weather to a rusty red color like those in the neighbourhood of Drás, already noticed. The mineralogical composition of these Pangong rocks affords by itself alone abundantly sufficient evidence to show that they are the equivalents of the slate series of Drás and of the country to the south of Tánkse.

At the north-western extremity of the Pangong lake, where the original relations of the rocks have been greatly disturbed by faulting and inversion, there occurs a great local development of a glistening white saccharoid quartzitic sandstone or quartzite, which superiorly gradually becomes calcareous, and passes by imperceptible degrees into a pale blue limestone. This rock overlies the slate series of the Pangong lake, and is apparently faulted against the ridge of gneiss to the south. This very characteristic saccharoid sandstone and limestone is precisely similar in mineralogical composition to the rocks underlying the Triassic series in South Rupsu, which we shall subsequently show to be probably of Carboniferous age. This identification confirms our conclusion as to the Silurian age of the slaty rocks of Pangong and Drás, the former of which underlie the sandstone and limestone.

Some miles to the south-east of the village of Shushál, at the Saki Lá, and elsewhere in the neighbourhood, there occur other outlying masses of blue limestones and white sandstones, which seem undoubtedly to be the same as those at the north-western end of the Pangong lake.

The Pangong slates lie to the north against a ridge of gneiss which runs in the normal Himalayan strike, on the line of the Marsemik pass. To the south-east of the Tátar camp at Chagra, the slates appear to be faulted against the gneiss, but to the north-west of a spur of gneiss running towards the south from Chagra, the slates conformably overlie the gneiss. The highest beds of the gneiss consist of alternations of light and dark bands, some of the latter being garnetiferous, like similarly situated gneiss in Pángi.[1] The gneiss of the Másemik Lá itself is usually porphyritic like that of Tánkse; to the north-west it is continued to the valley of the Shyok, and to the south-east I have traced it some distance over the border into Chinese Tibet. This ridge of gneiss appears to form an anticlinal axis, since on the north side of the Másemik Lá it has a north-easterly dip, and is overlaid conformably by slates, sandstones, jaspideous rocks, and the before-mentioned massive, slaty-sandy, or trappoid rock, so characteristic of the Drás Silurians. Many of the higher beds of the crystalline series consist of a dark-colored hornblendic rock with bronzite, similar to a rock which occurs in the same position in the Tánkse valley section. These massive trappoid rocks were apparently considered by Dr. Stoliczka[2] to show some signs of an igneous origin, and also to show some resemblance to the Silurian series of Srinagar; my own opinion is, that none of these rocks are of igneous origin, though they do, undoubtedly, very closely resemble some of the trappoid rocks of the Kashmir Silurian series, some of which have probably been brought to their present condition by metamorphic action.[3] From the summit of the Másemik Lá to the bed of the Cháng-Chenmo river, we have a generally ascending section through these same slaty rocks: a short distance on the north side of the pass, some of these rocks have been locally altered into a dark-colored gneiss, similar in character to that which I have already referred to, as occupying a corresponding position in the Tánkse valley. On the Cháng-Chenmo river, the slate series seems to be faulted against massive Triassic limestones, which I shall notice again in the succeeding section of this paper.

Dr. Stoliczka[4] seems to have considered that the gneissic rocks of the Másemik Lá were an altered portion of the slate series of the Cháng-Chenmo valley, and that consequently both were of Silurian age. There appears to me, however, to be a clear case of the superposition of the latter on the former, as in the other sections of similar rocks already described.

The rocks to the south of the Cháng-Chenmo valley, as I have said, were referred by Dr. Stoliczka[5] to the Silurian. Dr. Stoliczka also compares these rocks to the trappoid rocks of Srinagar, whence we may conclude that he also considered them to be Silurian. Both these rocks are, however, similar in character to those to the south of Drás, which Stoliczka[6] at first classed as Carboniferous, but which appear to me to be Silurian.

[1] Rec. Geol. Surv. of India, Vol. XI, p. 54.
[2] Manual of Geology of India, p. 653.
[3] See Rec. Geol. Surv. of India, Vol. XI p. 36, *et seq.*
[4] Geology of Second Yarkand Mission, p. 16.
[5] *Ibid*, p. 16.
[6] Mem. of the Geol. Surv. of India, Vol. V, p. 349.

This completes the description of the older palæozoic rocks of the Drás district, and of the northern bank of the upper Indus, as far as I am at present acquainted with them. A further discussion as to their precise geological age, and as to their relations with the palæozoics of other regions of the Himalaya, will find a more suitable place in the concluding section of this paper.

## II.—ROCKS NORTH OF CHANG-CHENMO RIVER.

In the previous section of this paper, I have traced the Drás slaty series as far as the left bank of the Cháng-Chenmo river, where it is separated, by what seems undoubtedly to be a faulted line, from a totally distinct series of rocks which forms the low cliffs on the opposite bank; the two series of rocks occur on a broken anticlinal axis.

The rocks on the right bank of the river are to a great extent composed of the characteristic white Triassic dolomitic limestone so frequently referred to in my former papers: a short distance north of the river, these rocks are traversed by a synclinal axis. The higher beds exposed in this synclinal are hard and crystalline, while the lower beds consist mainly of a soft white dolomite like that of Amrnáth cave in the Lidar valley of Kashmír; some soft reddish shales and a brecciated red conglomerate occur locally in the lower beds. *Megalodon* is of common occurrence in these limestones, and Dr. Stoliczka also obtained from them *Dicerocardium*;[1] there can, therefore, be no doubt as to their age.

To the northward these Triassic dolomites are underlaid by carbonaceous shales, not unfrequently containing crinoids and, according to Dr. Stoliczka-fucoids, and then again by dark slaty shales, sandstones, and occasional lime, stones, forming a somewhat folded series. Still further north, these rocks are underlaid by an anticlinal of rocks which seem to be the Silurian Drás series, which, according to Dr. Stoliczka, are again succeeded further north by Carboniferous and Triassic rocks, the latter probably forming the greater part of the dreary plains of Depsang, to the north of my map.

From the relations of the crinoidal shale and sandstone series to the Trias dolomite, I consider that the former rocks must undoubtedly be considered as of Carboniferous age—an opinion also held by Dr. Stoliczka who noticed their resemblance to the rocks belonging to that period in Spiti.

In the Cháng-Chenmo valley the notes of Dr. Stoliczka[2] make mention of some sandstones and conglomerates which he doubtfully considers as the representative of the Ladák Eocenes. These rocks are also much mixed with shales, and when I first entered the Cháng-Chenmo valley, I was at once struck with their resemblance to the Tertiaries; the sections are a good deal obscured by debris, but I found a portion of a conglomerate, which is strikingly like the Tertiary conglomerate of Miru (described below), distinctly underlying the Trias dolomite; and I think that these doubtful rocks belong to the Carboniferous series, the strong resemblance of which to the Tertiaries elsewhere will be noticed in the sequel. There are certainly no Eocene rocks on the Pangong lake, such as are

[1] Geology of Second Yarkand Expedition, p. 17.

[2] *Ibid.*, pp. 17-18

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referred to (probably by some clerical error) in the above-quoted passage from Dr. Stoliczka's notes.

### III.—Rocks of the Ladák and Zánskár basin.

I now come to the consideration of a series of rocks mostly newer than those of which I have already treated, which occupy a large elliptical area bounded to the north by the crystalline series described in the last section, and to the west and south by the Silurians which rest on the gneiss of the Zánskár range, already described in a previous paper.[1] The area occupied by these rocks comprehends a considerable portion of Ladák and nearly the whole of Zánskár, together with parts of Rupsu and other districts. As Ladák and Zánskár form the greater part of this area, it may be well termed the "Ladák and Zánskár basin." The whole of this large area has not at present been completely surveyed, owing to the very difficult nature of the country, but sufficient is known to indicate the general distribution of the rocks. I have said that the greater portion of the rocks in this area are newer than those previonly treated of; but from the south-eastern extremity of the basin a ridge of older rocks runs up, separating this end of the basin into two divisions. I shall treat of the rocks of this area in their serial order, commencing with the Tertiaries. It may be observed that the long axis of this basin or ellipse has the normal Himalayan north-westerly and south-easterly strike.

#### *The Tertiaries.*

The Tertiary series forms the north-eastern band of the area under consideration and, rests immediately on the Ladák crystallines. Coming from the west, these Tertiary rocks are first met with close to the town of Kargil, where they rest unconformably upon a denuded surface of the syenitic gneiss, and have a low and regular dip to the south-east. Masses of the gneiss may here and there be observed within the Tertiary area, protruding through the newer rocks. The lower beds of the Tertiaries near Kargil consist of soft grey and brown sandstones, shales, slates, and limestones, with here and there bands of conglomerate. Near the village of Pashkám the dip of the rocks has increased, being about 40°, and the higher beds, which are here well exhibited, consist of bright purple and green shales and sandstones, with occasional bands of a yellowish sandy limestone.

The northern boundary of the Tertiary zone is continuous with the southern boundary of the Ladák crystallines, and need not be exactly traced, and I, therefore, at once proceed to describe certain sections of the Tertiaries which will best exhibit the general characters of these rocks.

It may, first of all, be observed as a very important point, that along the whole of the northern boundary of these rocks, from Kargil to south of the Pangúr lake, (a distance of nearly 200 miles), the dip of these rocks is to the south-west, and that to the westward of Leh the same dip continues (with an occasional exception) throughout the entire width of the series. For some distance to the west of Leh this dip seldom exceeds 30° or 40°, and is of great regularity,

[1] Rec. Geol. Surv. of India, Vol. XI, p. 52.

and free from contortions. To the east of Leh these rocks, except along the northern border, have undergone a greater amount of disturbance.

The sections which exhibit most clearly the relations of the Tertiaries and the gneiss are found below the point where the Kashmír and Ladák road enters the valley of the Indus at Khalchi Near the village of Inamdoh the lower Tertiaries, here consisting chiefly of slates and sandstones, are seen resting unconformably upon a denuded escarpment of the gneiss. The surface of the escarpment has an average slope of about 25° to the south-west, this slope being irregular and bearing numerous hillocks and hollows: the dip of the gneiss is to the north-east.

The Tertiaries rest upon this sloping and denuded surface with a dip slightly lower than the plane of the slope. The lowest beds of the Tertiaries, which occur at the base of the slope, are cut off higher up by the projecting hillocks of gneiss, while the higher beds extend considerably further up the slope, thus showing a clear case of overlap. Numerous analogous sections may be seen in the neighbourhood, but the one quoted affords ample evidence to prove that the junction between the two series of rocks is a natural one, and that the Kailás crystalline range formed the old shore line of the gulf in which the Tertiaries were deposited.

I have said that at Inamdoh the lower Tertiaries consist of slates and sandstones; this composition is, however, not constant in the neighbourhood, since we not unfrequently find the lower slates replaced by coarse conglomerates containing rolled pebbles of the crystalline and other rocks. This conglomerate is of great thickness on the Khalchi and Dhúmkar (Dhumkur) streams, and it seems, from here to Leh, to occur on all the tributary streams descending from the Kailás range of crystallines to the Indus, and not in the intervals between such streams. If I am right in this interpretation, and I think I am, we must conclude that the drainage system of the southern side of the gneiss range followed the same approximate lines during the deposition of the Tertiary rocks, as it does at the present time.

A transverse section from north to south of the Tertiaries at Khalchi may be taken as a typical example of the series in this district. The lower beds, as we have already seen, are composed either of conglomerates, grits, sandstones, or slates, according to their relative position to the streams. The sandstones not unfrequently show ripple-mark, and the slates are generally grey in color, very hard, and almost indistinguishable in hand specimens from the palæozoic slates which occur to the south of the Tertiaries. The succeeding zone of beds consists of orange and brown calcareous sandstones, with occasional shales. These are followed by purple and green shales which are almost indistinguishable from some of the Subáthu rocks, and which are well represented on the Indus at Khalchi and Basgo. Between the villages of Kalchi and Nolra, in the Indus valley, a thick band of coarse, blue, shelly limestone overlies the colored shales. This limestone may also be seen on the Kashmír and Ladák road at the junction of the Láma-Yuru stream with the Indus, and again on the Zánskár river to the south of Nímo, so that it doubtless forms a continuous

band. In this limestone near Khalchi[1] I found a species of *Turbo*, and numbers of little disks which I believe to be Nummulites, though their structure is obliterated. On the Zánskár river, on the other hand, nummulites are extremely abundant in this limestone, and water-worn pebbles exhibiting sections of these fossils show the banks of the Indus at Nimo.[2] The nummulite, which is characteristic of this limestone, is, Mr. Blanford informs me, *N. raymondi*, an Eocene species, which fixes the age of these rocks: this species with *N. exponens* were obtained from these rocks by Dr. Stoliczka.

In the Indus valley between Khalchi and Nimo the nummulitic limestone is overlaid by several feet of a coarse conglomerate, containing pebbles of the underlying limestone: this conglomerate is apparently conformable to the limestone, and is succeeded by shales and slates. The Tertiary sedimentary series near Khalchi may be tabulated as follows:—

| | |
|---|---|
| UPPER | Shales and slates.<br>Limestone conglomerate<br>Nummulitic limestone. |
| MIDDLE ... | Purple and green shales and sandstones.<br>Orange and brown calcareous sandstones and shales. |
| LOWER ... | Grey and brown slates, sandstones, grits, or conglomerates; the sandstones often ripple-marked. |

Such is the normal section of the Eocenes at and below Khalchi: above the latter place, on the other hand, a very different condition prevails in the lower beds. On the Saspúl stream the boundary between the Eocenes and the Palæozoics runs close to the upper Kashmír and Ladák road. The lower Eocenes, which are inclined to the south-west at an angle of about 25°, consist of very soft brown and yellow sandstones, very frequently showing cross-bedding. In these sandstones are embedded vast quantities of blocks of the gneiss of the Kailás range, many of them several feet in diameter. Some of the isolated blocks showed the sandstone strata bending down below them, as if they had been dropped from above on to the still soft sand: two blocks were polished in a manner suggesting ice-action. The soft sandstone, with its boulders, lies unconformably on the gneiss, corresponding in position to the lower slates and conglomerates of the Khalchi section: it is overlaid by harder green shales and the middle Eocenes. Near the village of Ling the lowest strata consist of soft colored gypseous shales with occasional bands of a compact buff limestone; this limestone contains numerous specimens of a large species of *Estheria*; these strata are again overlaid by the purple Subáthu-like rocks. At Nimo again, there occur soft sandstone strata with embedded gneiss blocks, which are very

[1] It is mentioned by Mr Davidson, in describing some fossils collected in Ladák by Col. (then Capt.) Godwin Austen, (Q. J. G. S. L., Vol. XXII, p. 88) that Hippurites were seen in a rock at a place called Kalatys on the Upper Indus; I think that Kalatys must be the same place as Khalchi, which is also called Kalatse. I should, however, be very much inclined to doubt the occurrence of *Hippurites* either at this place or anywhere else along the Upper Indus, the course of which lies in or near the Tertiaries.

[2] I spell this name and numerous others without the initial S, which seems generally to be omitted in pronunciation. Similarly, Nolra for S'Nolra, Kio for S'Kio, Tok for S'Tok. Properly also Piti for S'Piti, but the spelling Spiti has acquired a general acceptance.

slightly inclined, but which from their structure seem to correspond with the lower Eocenes of the Saspúl stream; their relations to the higher Eocenes are not, however, well displayed, and to the south-east they are concealed by a modern boulder deposit, which also covers the base of the Tertiary series near Leh, where it has been much denuded away along the valley of the Indus. Above Leh, however, near the village of Arpa, we find the hard gneiss conglomerate occurring low down in the Tertiary series, underlaid along the bed of the Indus by soft gravels, conglomerates, sandstones and clays with a south-westerly dip of about 15°. The conglomerate contains pebbles of a trap, which is thus shown to be of *infra*-Eocene age, but whose origin is not certain: the lowest conglomerate also contains pebbles of blue limestone and buff dolomite probably derived from rocks of the Carbo-Triassic series, and indicating former outcrops of these rocks now probably concealed by the Tertiaries. Occasional blocks of gneiss, several feet in diameter, occur in the sandstones. From the softness of these rocks they have in great part been denuded away by the Indus, and only patches remain here and there.

I can but think that ice-action has played some part in the formation of these lower Eocene strata, as it seems to me very difficult to imagine that water power alone could have placed these blocks in their present position without scouring out the soft sand in which they are embedded. I have, however, no positive proof to bring forward in support of this view.

I will now describe two sections taken across the nummulitics higher up the Indus than the former, the first being an ascending and the second a descending section. The first section is taken from the Indus valley below Leh to Kio in Zánskár. The lowest nummulitics exposed on the Indus near the village of Phay, consist of brown and green sandstones, mingled with coarse conglomerates and grits; the sandstones are often ripple-marked, and the pebbles in the conglomerate consist mainly of gneiss, while the grits are composed of coarse gneissic sand precisely similar to that which at the present time is found in the valley of the Indus. In the higher part of the series, near Urúcha, purple and green shales and slates succeed and partly replace the grits, forming an anticlinal resting upon green and brown splintery shales. The higher slates contain numerous bands of earthy limestone abounding in nummulites: the latter are particularly common near the village of Shingo,[1] where I also obtained a species of *Conus*. The rocks are here much folded, but the foldings are regular and open, and never show the minute contortions and crumplings so characteristic of the older rocks. Some 2 miles above the village of Kio the nummulitic rocks are overlaid by several hundred feet of a coarse conglomerate, which is here nearly vertical. The relation of this conglomerate to the shales is not very clear, but it appears to lie in a synclinal axis, being again underlaid by colored shales nearer Kio; the great mass of purple shales are, however, unrepresented below the conglomerates at Kio; close to the latter place the Tertiaries are underlaid unconformably by Carboniferous rocks. The higher Tertiary conglomerate, here and in other parts of the same line, contains numerous pebbles of the

[1] The village of Shingo is placed in the Atlas Sheet 1½ or 2 miles too near to Kio.

underlying nummuliferous limestone, clearly showing that the former rock is the newest of the Tertiary series.

The next section is taken down the Gía river from Látho to Upshi on the Indus. On the left bank of the river at Látho the upper conglomerates are nearly vertical, but with a slight northerly dip: they rest to the south on green and purple shales, with false bedding, which at first sight has somewhat the appearance of unconformity; this is, however, but a local condition, and on either side conformability is clear. The conglomerates, which can be traced continuously along the southern border of the Tertiary zone from Kio to this point, form a regular synclinal axis, and as they descend gradually alternate with greenish-colored sandstones: they contain pebbles both of the older Tertiary and of the neighbouring Palæozoic rocks. Further down the Gía river, these conglomerates are underlaid by green and red shales, sandstones, grits and conglomerates; and the whole series is much contorted. Near the village of Míru, the highly colored shales are underlaid by a considerable thickness of conglomerate: these conglomerates contain chiefly pebbles of gneiss, of carboniferous quartzitic rock, of some unknown silicious rocks, and irregular fragments of the lower Tertiary shale. This conglomerate has acquired a kind of false slaty-cleavage, splitting into thin plates, right through the pebbles, and parallel to the stratification. Below the conglomerate we find an anticlinal axis of brown and green crumbly shales and greenish sandstones, which are again overlaid, towards the Indus valley, by the red shale series. At the very base of the Míru anticlinal there occur some brown and black carbonaceous shales alternating with bands of quartzite, which correspond so exactly in mineralogical character with the Carboniferous rocks of Gía (see below), that they are, I think, the same. These lower rocks seem to have the same dip as the Tertiaries, and as the two are very similar in mineralogical character, it is not easy to distinguish between them. The great similarity between the Eocene and Carboniferous shales at Shargol will be noticed below. If the identification of these Carboniferous rocks is correct, it would appear that we have here a case of parallelism between these rocks and the Tertiaries, and that the former must have been approximately horizontal at the time of the deposition of the latter.

Below Míru there is an alternating series of red and green shales and sandstones, with occasional bands of gneiss conglomerate. About 2 miles above the village of Upshi, these rocks are underlaid by hard and coarse gneiss conglomerate, several hundred feet in thickness, again underlaid by the softer rocks of the Indus valley, already referred to. No nummulites were met with in this section.

From the preceding sections it seems to me probable that the green and brown crumbly shales of Míru and Urúcha, together with some of the overlying conglomerates, are the equivalents of the lower gneiss conglomerate of the Indus valley, since both these groups are overlaid by the red shale series. It is further not improbable that the red shales once overlapped the gneiss conglomerate in the Indus valley, and extended some distance further up the crystalline rocks of the Kailás range.

It will be noticed that throughout the Tertiary series (above the gneiss con-

glomerates), there is evidence of local contemporaneous denudation, and that the southern conglomerate is formed in part of fragments of the denuded nummulitic zone, which I have shown to be relatively high up in the series. I have also shown that these higher conglomerates are underlaid by only a small thickness of shale, on their southern border, and it, therefore, seems probable that these newer strata overlapped the older along this border, such overlap being possibly due to local subsidence.

It now remains to treat of the southern boundary of the Eocenes, in the course of which we shall have to discuss a large mass of volcanic rocks which occur along this line. Commencing our survey at the western extremity of the zone, we find that the purple shales of Pashkám are overlaid by a great mass of basaltic trap which here consists of greenish anamesite, weathering to a pale brown color. South of Pashkám the traps may be traced continuously to Shargol (Shergol), a width of 10 miles, their western boundary running south-south-east from Kargil and adjoining the Palæozoics of Tashgám. At Shargol we find outh of the main trap outflow, a band of soft yellow calcareous sandstones, and purple, green, and black shales, exactly resembling the sedimentary Eocenes of Pashkám, and which are doubtless part of the same series. This band may be traced along the southern border of the trap as far as Múlbeck. The rocks of this band are much mixed up with trap, and in many places within the trap area masses of altered sedimentary rocks are met with, which are probably fragments of the Tertiaries which once extended continuously over this area, but which have been broken up and altered by the subsequent intrusion of the trap. From Shargol the southern boundary of the trap runs a little to the north of Múlbeck, and thence north of the Kashmir and Ladák road. At and near Báma-Yuru, the trap is much mixed up with Palæozoic rocks which I shall refer to subsequently; east of the last-named village the southern boundary runs north of the village of Wanla, and thence on the north of the stream flowing from the Choki-Lá. From Pashkám the northern boundary runs for some miles in an easterly direction, then bends to the south-east till it touches the Indus at Khalchi, from which point it again leaves that river and forms the summits of the high range on the left bank, gradually dying out among the sedimentaries to the west of the Zánskár river.

The trap throughout this series consists of fine-grained anamesites, green-stones, basalts, and serpentines, with occasional amygdaloids; it is never porphyritic, and when worn into pebbles acquires a brown-black glaze like the darker varieties of hæmatite.

I have already said that these traps die out a little to the west of the Zánskár river, in consequence of which the main mass of the sedimentary Tertiaries comes into direct contact with the Carboniferous rocks, which form the zone to the south of the Eocenes. Between Kio and the Zánskár river, the Eocenes, with a low northerly dip, rest upon and overlap, the Carboniferous rocks, masses of the latter often protruding through the former, showing that we have another natural boundary, indicating the original southerly limit of the Eocene series.

In the Zánskár river, during its course through the Tertiaries, there were found, during the summer of 1878, large masses of pure native copper which had

been washed from the neighbouring rocks. The copper occurred in irregular nodules of many pounds weight. I could not discover the copper *in situ*, and cannot therefore say positively whether it was derived from the Tertiaries or from the older rocks further south.[1]

To the south-east of Kio the Tertiary boundary runs near the right bank of the Markha river, crosses the Ladák and Kulu road at Látho, thence continues along the left bank of the Indus towards the Chinese frontier. The coarse conglomerates that form the highest beds of the series between Kio and Látho may be traced far to the east of the latter place. On the Markha river between those two places, masses of trap occur on the southern border of the Eocenes. This trap is of a highly crystalline structure, and not like the compact greenstones and serpentines of Shargol.

The line of occurrence of this trap is generally near the junction of the Palæozoics and the sedimentary Tertiaries, as is well seen near Gía, where the trap has clearly intruded among the Palæozoic limestone, which is here full of *Encrinites*.

On the Markha river and to the south-east of Gía, numerous trap-pebbles are included in the upper Tertiary conglomerate; but it is not clear that these pebbles belong to the same mass of trap as the one on this line.

The large mass of trap on the upper Indus above Leh forms a ridge-shaped mass, extending between the sedimentary Tertiaries to the north and the gneiss of Rupsu to the south. The upper Tertiary conglomerate near Gía and to the eastward contains pebbles of trap, of crinoidal Carboniferous limestones, of Rupsu gneiss, and of the lower Tertiary rocks. South-east of Gía the band of Carboniferous rocks dies out, and the Tertiaries are in direct contact with the gneiss of Rupsu.

Along the whole of the southern border of the Tertiaries to the east of the Zánskár river, these rocks have been much disturbed, and are not unfrequently inverted; from the distinct occurrence of overlap here and there, it seems probable that this boundary, like the northern, indicates the original limit of the area in which the rocks were deposited: the trap has, however, probably disturbed the original relations of these rocks.

The occurrence of nummulites in the higher Eocene rocks proves that these beds are of marine origin. Many of the lower littoral beds, on the other hand, from their heterogeneous composition, and from the frequent occurrence of cross-bedding, appear to me very probably to be of fresh-water or brackish origin. In the lower beds near Kargil, Mr. Drew obtained some gastropods allied to *Melania*, and some bivalves which seem to me to be *Unio* and *Dreissena*, though Dr. Stoliczka[2] considered them as *Pholadomya* or *Panopæa*; if my interpretation be correct, it confirms the fresh water origin of these rocks, which is borne out by the occurrence of an *Estheria* near Leh.

The above facts lead, I think, to the conclusion that the nummulitic rocks of the upper Indus valley were deposited in a narrow arm of the sea (as was

[1] General Cunningham ("Ladák," p. 22) says that the name Zánskár (or more correctly Zángskár) means "white copper" or brass; and at p. 234 of the same work, he concludes from this meaning that copper must occur in that country, though he could not hear of it.

[2] Mem. of the Geol. Surv. of India, Vol. V, p. 343.

suggested by Dr. Stoliczka), the borders of which were rendered brackish b the influx of fresh water. Subsequently to the deposition of these rocks, th southern border of the western half of the zone was broken up by a large mas of basaltic trap which followed the normal strike of the Himalayan rocks, a being in all probability the line of least resistance. The Kailás range formed at a lower elevation the northern shore line of this gulf, while the southern shore line in all probability followed the northern boundary of the Palæozoics o the Zánskár basin, and of the trap of the upper Indus.

At the time of the deposition of the nummulitics, the upper Indus valley must have been a wide depression below the level of the sea, flanked on either side by land. Since the Eocene period this valley has been raised to an elevation of 10,500 feet above the sea-level below Leh, and it is in all probability owing to this elevation that the Tertiaries have obtained their present generally south-westerly dip. This elevation of the Tertiaries (together, of course, with the surrounding rocks) to the north-west of the Zánskár river, must have been so gradual and even as not to disturb the original relations of the rocks, and, judging from the southerly inclination of the Tertiaries, was probably of greater vertical extent on the northern than on the southern side of the Indus. To the south-east of the Zánskár river, where the Tertiaries attain the enormous elevation of 21,000 feet (as in Tok (Kanri) peak, opposite Leh), the disturbance which they have undergone is considerably greater than to the west (where their elevation is less), and their southern boundary is often faulted.

In the former area, however, these rocks do not seem to have undergone the puckerings and crumplings to which the Palæozoics have been subjected, the movements causing which would seem to have taken place before the Eocene period It seems not improbable, from the prevalence of the south-westerly dip in the Tertiaries, that their northern border was first elevated, and that to the east of the Zánskár river, the higher conglomerates were deposited in a narrow valley at the base of this newly elevated Tertiary land, which was then rapidly undergoing denudation.

I am thus led to the belief that the great contortion which the pre-Tertiary rocks of Ladák have undergone took place in great part, at all events, previously to the nummulitic period, and from the presence of Jurasso-Cretaceous rocks (and no newer secondaries) in Zánskár (see below), that this contortion and denudation took place in the later Cretaceous period when the country (except the Indus valley) first emerged from the sea, beneath which it has probably ever since been buried.[1] From his observations in the Sub-Himalayan region, Mr. Medlicott[2] came to the conclusion that the contortion of the older rocks there took place after the Nummulitic period, and he pointed out the importance of comparing this relation with that in the Central Himalaya, where a different condition might prevail.

[1] Against this view there is the apparent parallelism between the Tertiaries and Carboniferous on the Gía river, which would indicate, if rightly interpreted, that here the great part of the disturbance was of post-Tertiary age. This is borne out by the greater amount of metamorphism and contortion which the Tertiaries to the south-east of the Zánskár river have undergone in comparison with those to the north-west.

[2] See "Manual of Geology, India," p. 634.

The Indus valley Nummulitics seem to indicate that the enormous elevation of the Central Himalaya did not take place at all events till post-Eocene times, while the elevation and contortions of the outer Siwaliks render it probable that the elevation of the whole Himalayā has occurred in great part since the period of the older Pliocene.

It may not improbably be, that in the Ladák Himalaya, lateral crushing had taken place before the Eocene, and brought the pre-Eocene rocks approximately into their present positions, during which a great smashing and crushing of these rocks must have taken place; the pre-Eocene rocks were then denuded. During the deposition of the Ladak Eocenes there was a pause in the lateral crushing action succeeded by another period of lateral crushing; this second crushing must have raised the Ladák mountains to their present height, during which elevation the Tertiaries were not so much smashed up as the lower rocks during the first crushing, but were, so to speak, carried up on the top of them. The post-Eocene period of lateral crushing was also probably post-Pliocene, and was the one which also crushed up the Siwaliks. These latter rocks with their underlying Nummulitics, being on the boundaries of the central elevated mass, would necessarily undergo much more crushing and smashing than the Eocene rocks of Leh, which, as I have said, might be carried up by the lateral movement on the top of the denuded older rocks with but comparatively little crushing.

*Older Rocks.*

I now come to the consideration of the pre-Tertiary rocks of the area under discussion, and commence my survey at the north-western end of the basin.

When treating of the slaty series of Drás, I have already shown that those rocks do not extend to the westward of a line running south-south-east about 16 miles to the east of the Kúrtse, where they are cut off by newer rocks. I have also shown that the Tertiary zone does not extend much to the south of either Shargol or Múlbeck, and a line running at first east and then south-east of the latter place. The rocks we have now to consider occupy the angle between the two lines, and extend far to the south-east into Spiti: a few of these rocks extend within the Tertiary area in the neighbourhood of Láma-Yuru.

Before going further, it may be well to mention that the rocks now to be noticed range from the Silurian to the Cretaceous, and that the great mass of those above the Carboniferous consist of the Triassic series. Most of these rocks were originally named by Dr. Stoliczka in the Spiti district, where they are all fossiliferous, and their divisions are tabulated on pp. 135 and *seq.* of his above quoted memoir. The strata above the Carboniferous (Kuling) were divided into upper Trias (Lilang), Rhætic (Para limestone), upper Rhætic or Lower Lias (Lower Tagling), and various higher groups of Jurassic and Cretaceous age. In most of the country examined by me where supra-Carboniferous mesozoic rocks occur, I have only here and there been able to identify the separate groups of Stoliczka, which all form part of one great rock-series, easily recognised by the great prevalence of limestones and dolomites. I have not been able to color these different groups separately in the map, and they are, therefore, all embraced in the large area colored sienna in the map, which must, accordingly,

be understood to comprehend strata ranging throughout the upper Trias (under which I include Rhætic) to strata of lower Liassic or upper Rhætic (lower Tagling) age. As I shall notice, there may possibly be some even newer strata included here and there in the area, though in the absence of fossil evidence I cannot be certain. Whenever I have been able to recognise any of Stoliczka's minor divisions I have mentioned them. It may be observed that in his second paper on Western Tibet, Dr. Stoliczka was disposed to unite the Trias and Rhætic [1]

I commence my examination of the pre-Tertiary rocks of the Zánskár basin at its north-western extremity.

To the south and south-east of Shargol (Shergol), to quote the words of Dr. Stoliczka, [2] "the higher hills all consist of Triassic limestone, alternating near the base with rather highly metamorphic, and sometimes strongly carbonaceous shales, which it is very difficult to distinguish from the Tertiary beds," which I have already shown to occur to the north of and at Shargol. Dr. Stoliczka goes on to say that the determination of the Triassic limestone is tolerably certain, and that it is the same as that which occurs above Drás. The latter was considered by Stoliczka[3] as the representative of the Keuper (Lilang) in its lower part, and apparently of the Para limestone in its upper and more dolomitic part. We shall subsequently see that the Shargol limestone underlies other dolomitic strata which are probably the representative of the Para, the Shargol limestone being the Lilang.

It does not appear that Dr. Stoliczka found any fossils in the Shargol limestone: in the stream running to that place from the south there, however, occur numerous blocks of a blue limestone full of a species of a large *Megalodon*, though I did not find the fossil *in situ*. These fossils seem to differ from *Megalodon triqueter*,[4] characteristic of the Para limestone, by the larger size of the umbones, and by the deeper groove between the two valves. To Dr. Feistmantel and myself the species appears to be indistinguishable from *Megalodon gryphoides* of Gümbel,[5] characteristic of the European Keuper. We have, therefore, pretty fair evidence that the Shargol limestone is upper Trias.

Dr. Stoliczka, in the notes of the Yarkand journey, goes on to say that the Triassic limestone can be traced to the south of Kárbu (Kharbu) and the Fotu-Lá; and he further observes, that this limestone near Kárbu and on the Fotu-Lá is underlaid by shales, which he classes as Carboniferous, and which he traced as far as Láma-Yuru. These shales are generally carbonaceous and weather to a peculiar light brown color, and as they underlie the upper Triassic Shargol limestone, they may in all probability be classed as Carboniferous, since according to Stoliczka,[6] the Lilang (upper Triassic) series in Spiti overlies (with here and there unconformity) the Kuling (Carboniferous) series; the Permian and Lower

[1] Mem. Geol. Surv. India, Vol. V, p. 352.
[2] "Scientific Results of Second Yarkand Expedition," Geology, p. 13.
[3] Mem. Geol. Surv. India, Vol. V, p. 349.
[4] "Manual of Geology of India," Pl. II, figs. 8, 8a.
[5] "Sitzungsb. d. k. Akad. Wien.," Vol. XLV, p. 372, and figure.
[6] Mem. Geol. Surv. India, Vol. V, p. 64.

Trias (Muschelkalk and Bunter) being absent. Subsequently, however, Stoliczka incidentally mentions[1] shales of lower Triassic age in Rupsu, and it may possibly be therefore that the Shargol shales (as I shall frequently style these rocks) are partly of lower Triassic age. As, however, they are unfossiliferous, and as more to the south, they overlie metamorphic Silurians, there is little doubt, both in Stoliczka's and my own opinion, that they are mainly Carboniferous, and they have accordingly been so colored in the map.

Dr. Stoliczka, as I have said, mentions the difficulty which he found in distinguishing the Tertiary from the Carboniferous shales, and it is not quite clear to me to which group he referred some shales to the east of Shargol, which I think are certainly the Carboniferous; he speaks of "lumps and patches of it (Trias limestone) sticking out of the *so-called* Tertiary shales," as if he thought, as I think, that the shales were not Tertiary. I incline to think that the limestone in these shales is mainly in the form of lenticular masses, interstratified with them, though some of them may be outlying masses of the Trias overlying the shales.

Before discussing further the south-easterly extension of the Shargol shales, I proceed to notice two sections taken from the northern border of these shales to the south. The first of these extends from the Kashmír and Ladák road near Múlbeck up the ravine known as Múlbeck Rúng. Leaving the Kargil river, we first cross the blue limestone corresponding to the Shargol *Megalodon* beds, which has a southerly dip. These rocks are succeeded for a distance of about 3 miles by alternations of hard and massive white, green, and purple slates, with sandstones and limestones, the whole series being much folded, and its thickness difficult to estimate; these slaty rocks are much like those of the Trias of Tilel.[2] The slaty rocks seem to be succeeded by a great thickness of nearly horizontal strata of white dolomites and blue limestones, like those occurring in a similar position in Tilel, as described in my paper quoted above, and apparently corresponding to the higher part of the Trias of Drás (Para limestone); the slates between the *Megalodon* beds and the dolomites being much thicker than the intermediate (limestone and shale) beds at Drás. The dolomitic rocks continue across the ridge at the head of Múlbeck Rúng in a rolling series to the north of Gonpa Láma Serai, where they were noticed by Stoliczka (Rangdum Gonpa),[3] and are apparently faulted against the Silurians of the Drás series. Stoliczka merely noticed these strata from a distance, but speaks of them as "secondary deposits, undoubtedly of different formations." As I have said, I think, their highest beds are the topmost Trias (Para), and the series is undoubtedly the same as that which I have included in the Trias in Tilel and the Zoji-Lá.

The second section runs southward from the village of Hiniskot, on the Kashmír and Ladák road, across the Kangi-Lá. At Hiniskot itself we find cliffs of nearly vertical blue and buff limestones, corresponding to the Shargol *Megalodon gryphoides* beds, with a few slaty beds; these rocks continue in a rolled and much bent series till within some 2 miles of the village of Kangi, where we cross a synclinal axis in bright colored shaly slates, again underlaid by the

[1] Mem. Geol. Surv. India, Vol. V, p. 345.
[2] Rec. Geol. Surv. India, Vol. XII, p. 21.
[3] Mem. Geol. Surv. India, Vol. V, p. 347.

lower limestones nearer and at the village. The limestones seem here to form an anticlinal, overlaid again to the south by the colored slates, with one thick band of soft and dark colored shales, containing large ferruginous concretions. Higher up the Kangi stream, we find the slates extending as far as the village of Ampaltan, where we find them gradually succeeded by blue limestones, and these again by buff dolomites. These dolomites continue in a rolling series across the Kangi-Lá to the Silurian slates of Rundum, where they were colored in an unpublished map of Stoliczka's as Trias. This section is not very clear; the beds on the north are, I think, certainly the Lilang, and the southern dolomite the Para limestone; if this be so and the section correct, the intermediate slates must also be part of the Trias; they resemble the similarly placed rocks of Tilel. The thin band of black crumbly shales at Kangi with concretions makes a curious approach in mineralogical structure to the Spiti shales as described by Stoliczka: the other rocks do not, however, agree with the other Spiti Jurassics.

It may be noticed that at and below the village of Kangi, there occur in the bed of the stream numerous pebbles of a crystalline trap, with a rust colored weathering; these pebbles have been derived from a mass of trap occurring on snowy peaks, D 24 and D 25, to the eastward, to which I shall have occasion to refer subsequently.

Returning to the Shargol Carboniferous shales, we find them continued, as we have seen from Dr. Stoliczka's notes, to the eastward along the line of the Kashmír and Ladak road: north of Kárbu a few small patches of Triassic slates and limestones are found resting on the shales, and the latter are a good deal mixed with the Tertiary serpentine trap, especially near the nummulitic zone: these shales were traced by Stoliczka and myself, as noticed above, to Lámá-Yuru. Crossing the stream at Kárbu and proceeding in a north-easterly direction, we find the Carboniferous shales underlaid by slaty rocks, green, red, and black in color, which form the summit of the ridge on which Nindam station is situated. Among these lower slates Dr. Stoliczka[1] recognised the green (Silurian) rock of Drás; these slates are much mixed up with the serpentine trap. At Lámá-Yuru the Carboniferous shales are underlaid by the same slate series as occurs near Kárbu, and some beds of sandstone, with a south-westerly dip. The same slate rocks mixed with ribband jaspideous rocks like those between Tilel and Drás, and with the slaty sandy (trappoid of Stoliczka) rocks of the Drás river and the Pangong lake, occur in a descending series in the gorge leading from Láma-Yuru to the Indus. These rocks are, however, so intimately mixed up with the Tertiary trap, that it is exceedingly difficult to map them with any accuracy. To the eastward I have traced those slaty rocks to the village of Wanla, where they again underlie the Shargol Carboniferous rocks. Dr. Stoliczka says[1] that the colored shales and slates underlying the brown carbonaceous (Carboniferous) shales of Láma-Yuru are the representatives of his Múth and Bhaboh series (upper and lower Silurian): he farther thinks there are traces of syenite (central gneiss(?)) underlying these slates, though I did not observe them myself. Near the Indus the Silurian slates are cut off by the Tertiary trap. From the mineralogical composition of the rocks in the Láma-Yuru gorge, they

[1] Geology, 2nd Yarkand Mission, p. 13.

appear to me to be certainly the same as the slate series of Kashmír, Tilel, Drás, the Pangong Lake, and Cháng-Chenmo.

From the Fotú-Lá the Carboniferous band extends in a south-easterly direction, its northern boundary running through Wanla, and thence slightly north of the road across the Choki-Lá to the Zánskár river, where I shall take it up subsequently. The southern boundary runs near the village of Panjila, and thence in a south-easterly direction: near the village of Urchi there is a small synclinal in the lower shale-series, occupied by a patch of the bright-colored Triassic slates and limestones. Near Wanla a large proportion of blue limestone occurs in the lower Carboniferous shales, which is not unfrequently crowded with *Encrinites*. Iron also occurs in these rocks, and is worked in small quantities. To the south-east of Wanla, the Carboniferous strata consist of black flaggy slates, which, however, weather to the usual light-brown color, by which character they are readily distinguished from the older Láma-Yuru slates, which always weather black.

Close to Wanla there occurs a wide dyke of the Tertiary trap running in among the Palæozoics, which requires a moment's notice. On the south side of this dyke, between it and the Carboniferous shales, there occurs a considerable thickness of coarse vertical conglomerate, a good deal altered by the trap, and containing pebbles of the Trias limestone, and of the crystalline trap, already noticed as forming peaks Nos. D. 24 and 25. I cannot say whether or no this conglomerate corresponds to the higher Tertiary conglomerate near Gia; but since it has been jammed in between the trap and the Palæozoics in vertical beds, it affords the important piece of evidence that it is older than the trap, and that consequently the crystalline trap within the Triassic area is older than, and was denuded at the time of, the formation of the basaltic trap of the Indus.

A section through the secondary rock-series from the village of Panjíla, south of Láma-Yuru, to Yelchang bridge, on the Zánskár river, gives the following series of rocks. Leaving the shaly Carboniferous rocks near Panjila, we find the overlying Trias at first consisting of hard purple and green slates, which are nearly vertical, mixed with some calcareous and limestone bands: these are succeeded by softer and brighter-colored slates, like those of Kangi; while shortly below the village of Hanúpatta (Hunúpatta), we come upon blue limestones with a lower southerly dip. From Hanúpatta to the Sirsa Lá there is a succession of blue limestones and white dolomites, with a few slates, which form a rolling synclinal, the underlying poikilitic slates again appearing beneath the limestones at the pass itself.

These limestones and dolomites appear to me to be the Para limestones, and they contain sections of fossils which appear to be those of *Dicerocardium himalayense*, characteristic of this band. This being so, the underlying slaty rocks must be the Lilang series, the limestones of Shargol being represented by these slates; this section confirms the Triassic age of the rocks in the Kangi section.

From the Sirsa Lá to the village of Phatoksir and thence across the Shingi

(or Shingo, or Singhi) Lá[1] to Yelchang on the Zánskár river, there is a continuous succession of the same limestones and shales. For want of supplies I was unable to continue my journey beyond Yelchang, but Triassic. (Para) dolomitic limestone extended as far as I could see up the Zánskár valley. According to Dr. Stoliczka[2] the Zánskár valley near Zangla consists on either side of contorted Triassic limestone (Lilang ?) overlaid by the darker Para limestone on the higher ranges. To the south-east of Zangla near Niri-Sumdo (Niri-Chu), at the Shapadok-Lá, and the Saiji Lá, lower Tagling limestone (lower Lias) overlies the Para limestone; these are in turn overlaid by Spiti shales in small patches (the occurrence of the latter is roughly indicated on the map by yellow patches, while the lower Tagling is included in the sienna). I have no doubt but that the Trias of Yelchang is continuous with that of Zangla, with patches of Jurassic rocks occurring on the higher hills. I may observe that to one who like myself did not give the local names to the different limestones of the great Trias-Jura of this district (for, as in America, the Trias and Jura are one great rock series), it is exceedingly difficult to recognise these palæontologically different but mineralogically very similar limestones. General Cunningham[3] observes that limestones are found continuously across Zánskár from the Shinghi-Lá to the Líchi-Long-Lá, on the Ladák and Kulu road, where, as will be noticed below, the Trias seems to continue across Zánskár. I therefore conclude that the Triassic and lower Jurassic rocks form, with small exceptions, the whole of the central part of the great limestone ellipse of Zánskár.

Near the village of Thonde, in Zánskár, Dr. Stoliczka says[4] that "the Triassic beds are separated from the Silurian sandstones by a dark band of a greenstone-like rock, which I presume to be Carboniferous." These latter rocks have been provisionally so colored on the map, as there is a strong presumption from their position that they are rightly referred to that formation.

The trap occurring on peaks D. 24 and 25 must be post-Triassic age, though, from the amount of snow, I could not examine it closely *in situ*. It is distinguished from the Shargol trap by its more crystalline structure, and by the peculiar rusty brown weathering.

Reverting once again to the presumed Carboniferous rocks, which we have already traced as far as the village of Wanla, we find that from this point they continue across the Choki-Lá down to the Zánskár river, near the village of Chiling; thence their northern boundary is continuous with the southern boundary of the Tertiaries, which we have already traced. From Wanla to a

[1] Dr. Thomson is said to have brought nummulites from this pass (Mem. Geol. Surv. of India Vol. V, p. 354); this seems to have arisen from confusing this pass with the one to the north-east of the village of Shingo near Kio, which is often called Shingi-La, and under which name Dr. Stoliczka alludes to it when he found nummulites on it (sup. cit., p. 344); it is rather strange that the similarity of the two names did not strike Dr. Stoliczka when he wrote his paper. This error is repeated on page 14 of the Geology of the Second Yarkand Mission. Mr. Medlicott (Man. Geol. of India, p. 644) pointed out the probable error.

[2] Mem., Geol. Surv. of India, Vol. V, p. 346.

[3] "Ladak," p. 57.

[4] Mem., Geol. Surv. of India, Vol. V, p. 346.

long distance up the Markha river these rocks have a general south-westerly dip, and form a band of very uniform breadth to the north of the Trias. Near Kio, the lowest beds of the Carboniferous series which are exposed, are nearly vertical, and consist of blue-black limestone, traversed by veins of yellow quartz. Nearer Kio itself, the south-westerly dip becomes flatter, and the limestone is overlaid by brown shales and blue slates, with many bands of white and yellow quartz: many of the slates contain bands of carbonaceous matter, and are not unfrequently studded with small crystals of pyrite.[1] On the Markha river, a little below Kio, the yellow quartz is in great force, and gold-washing is carried on to a considerable extent in the detritus from these quartz-reefs. At Kio and in the neighbourhood, stems of *Encrinites* are of very common occurrence in the Carboniferous limestones, and at that place I obtained a coral closely allied to *Cyathophyllum*. To the south-east of Kio the mineralogical composition of the presumed Carboniferous rocks has the same general characters as those described above; the relative development of the limestones and shales is, however, locally very variable.

In noticing these rocks at Kio, Dr. Stoliczka observes,[2] "The nummulitic rocks are suddenly replaced by slates and carbonaceous limestones full of crinoid stems, which appear to be of Carboniferous age. All the way up from Kew (Kio) to the head of the Markha valley, nothing but these carbonaceous crumbly slates occur." No fossils were found in these rocks, and Dr. Stoliczka adds that there were probably representatives of the Silurian and Carboniferous among them. The slates of Kio are frequently full of small cubical crystals of pyrite. To the north-west, as we have seen, these rocks are continuous with the Shargol shales which we have classed as Carboniferous. To the south-west of Tso Moriri, I have traced this band into a series of slates noticed by Dr. Stoliczka,[3] who observes that "these slates can only belong to the Kúling (Carboniferous) series, being perfectly identical with the rocks of this (series) in mineralogical characters and geological position, underlying the Lilang limestone."

There is, therefore, every presumption of the whole of the blue bands on the map being of Carboniferous age.

To the south-east of the valley of the Markha river the band of Carboniferous rocks continues along the southern border of the Eocenes, till it finally dies out on the upper Indus, between the latter and the gneiss of Rupsu. On the Gía river the Carboniferous rocks have undergone great contortions; they consist at Gía itself of brown weathering shales mixed with blue quartzitic limestones generally in lenticular masses; the shales are often quartzitic and carbonaceous and dip generally towards the Tertiaries, which they frequently much resemble.

To the southward of Gía we have at first a folded series of these rocks, which, further to the south, is underlaid by hard blue slates and micaceous sandstones, similar in structure and position to the Silurians of Láma-Yuru. Near

[1] The composition of the Carboniferous series here is closely analogous to that of the Kiol series in the outer hills, which confirms my opinion as to the Carboniferous age of the latter (see Rec. Geol. Surv. of India, Vol. IX, p. 160).

[2] Mem. Geol. Surv. India, Vol. V, p. 344.

[3] *Ibid.*, p. 343.

the Tagalúng-Lá and to the west of Ralla St. there occurs a synclinal in these rocks, consisting of the Carboniferous shales, quartz and limestones; near the pass large lenticular masses of pure white saccharoid quartzite, like that of the Pangong Lake, occur in these rocks. In the centre of this synclinal there occur beds of dolomitic limestones, mixed with some reddish shales, which are probably the Lilang series. Dr. Stoliczka, in his notes on the Tagalúng-Lá[1] (Taglang), does not notice these limestone rocks, and speaks of all the rocks as belonging to the metamorphic series.

The Carboniferous rocks in the Tagalung synclinal are underlaid to the south by the slaty and sandy Silurians. Lower down the Zára river there is an anticlinal, to the south of which the slates gradually assume a gneissoid character, the crystalline rocks occurring as lenticular masses among the slates.

This gneiss and slates are again overlaid conformably to the south-west by the carboniferous rocks of Kio. The gneiss and slate series can be traced to the north-west nearly to the Markha river, where they form a wedge-shaped mass intruding between the Carboniferous rocks, which here split to receive them. To the south-east the slates and gneiss, which form one series, have been traced by Dr. Stoliczka to the south of the Indus, and across Rupsu to the south of Tso-Moriri and were classed by him as the equivalents of the Silurian. The gneiss is dark-colored, and very generally porphyritic, with large crystals, often 3 or 4 inches in length, of gray orthoclase. It is quite different in character from the white gneiss of the Kailás range, and when non-porphyritic is very like the altered Silurians of Tánkse. As the Rupsu slates and gneiss directly underlie strata which are certainly not newer than Carboniferous they must probably be of Silurian age, as suggested by Dr. Stoliczka, and consequently the equivalents of the slates of Drás and Tánkse. It will be noticed that the strike of the altered Rupsu Silurians is continuous with that of the unaltered Silurians of Láma Yuru, and the two probably belong to the same band.

To the south-west of the Silurians of Rupsu the Carboniferous rocks, which, as we have seen, split near the head of the Markha river, form a continuous band of nearly the same width, which I have traced to the south-east of the Kiang-Chú plain, whence the same band has been traced by Dr. Stoliczka in a south-easterly and southerly direction into Spiti, and which, as before said, to the south-west of Tso Moriri, underlies the Lilang limestone.

At Kiang-Chú the Carboniferous rocks consist of shales, frequently containing crystals of pyrite, like those of Kio, and alternating with large lenticular masses of blue quartziferous limestones; these are succeeded by banded limestones, alternating with highly carbonaceous shales. These shales continue for some distance in a V-shaped hollow up the valley leading to the Láchi-Long Lá; they are succeeded by blue, buff, and white limestones and dolomites which, with the occasional exceptions of small patches of carboniferous shales appearing beneath them in the valleys, continue to near Lingti. Near the top of the Láchi-Long pass there seems to be an anticlinal of Carboniferous shales underlying the dolomites. In these limestones and dolomites there are seen numerous sections of *Megalodon*

[1] Mem. Geol. Surv. India, Vol. V., p. 343.

and *Dicerocardium*, and most of the rocks may be taken as the equivalents both of the Lilang and Para limestones:[1] fragments of a *Lima* are not uncommon; and corals and crinoids are extremely common in these rocks. The thickness of this dolomitic series is at least 3,000 feet near the Láchi-La. In the Lingti valley the Para limestone with *Dicerocardium* occupies the upper part of the hills, underlaid by the Lilang limestone; the rocks have here undergone immense contortions and foldings. To the south-west of Lingti the Triassic rocks are underlaid by blue and reddish shales, with white quartzites and blue limestones: from their position and composition I have little doubt but that they are mainly Carboniferous; patches of similar rocks, with *Productus* and *Spirifer*, were noticed by Dr. Stoliczka[2] to the south-east of Lingti (Tsárap valley), underlying the Lilang limestone near Lámaguru (Yuroo. Stoliczka). I have traced the Carboniferous and Triassic rocks a considerable distance to the north-west of Lingti, and they are doubtless continuous with the corresponding rocks near Zangla, mapped by Dr. Stoliczka, overlying the Silurians of Padam.

To the south-east of Lingti, Dr. Stoliczka[3] observes that above the Lilang limestone at the bottom of the valley, the greater part of the Tsárap valley consists of the Para limestone full of *Dicerocardium himalayense* and *Megalodon triqueter*. The Para limestone in this district is of a light-blue color, with a marbling of white; it is very different from the white dolomites of the Drás river, which Dr. Stoliczka correlates with it; the Triassic rocks, however, appear to me to vary very considerably in composition. In the upper part of the Tsárap valley, according to Dr. Stoliczka, the higher hills consist of the lower Tagling limestone (lower Lias ?) with *Terebratulæ* and *Rhynchonellæ*: the summit of the Pangpo-Lá consists also of the same limestone, while the higher ridges near the pass are capped with Spiti shales, and Gieumal sandstones (upper Jurassic); and fragments of the Chikkim (Cretaceous) limestone were also found in the neighbourhood; these rocks must apparently rest unconformably on the lower Tagling. To the north of the Pangpo-Lá the lower Tagling limestone, according to the same authority, forms the prevailing rock, underlaid for a short distance by the Para limestone, which appears to be greatly developed to the south-east. Near Khiang-Shisha the limestone belongs chiefly to the Lilang group, and

[1] There may probably be representatives of the lower Lias (lower Tagling) on some of the higher hills. On page 38 of volume XXII of the Quarterly Journal of the Geological Society, Mr. Davidson in describing some fossils collected by Colonel (then Captain) Godwin-Austen, mentions some Brachiopods, said to have been obtained in a light gray limestone "near Lacholung-Lá, north side, in the Suru country in Thibet." In Suru there is no Lacholung-La that I am aware of, and I think the place referred to must be the Lachi-Long Lá in Rupsu. The said fossils are either Jurassic or Cretaceous, and if the above determination of locality be correct, rocks of one or other of these systems must occur probably on the higher peaks around the Lachi-Long. The crest of the pass shows carbonaceous shales in an anticlinal which I think are certainly Carboniferous, and undoubted Trias rocks with *Megalodon* occur near by. If the patches of newer rocks exist near the pass, they would be on the strike of similar rocks noticed by Stoliczka on the heights above the Pangpo Lá.

[2] Mem. Geo. Surv. of India, Vol. V, p. 342.

[3] *Ibid.*—I was prevented by want of supplies from examining this country more closely.

is underlaid to the north-east, as noticed above, by the Carboniferous series, which again overlies the metamorphic Silurians of Rupsu.

In the map accompanying this paper the whole of the great limestone series above the Carboniferous, from the Lilang to the lower Tagling limestone, is colored of one tint, and may be called the Trias-Jura. Owing to the variations in the mineralogical characters of these rocks, to the general absence of fossils, to the enormous contortions which the rocks have undergone, and lastly, but not leastly, owing to the difficult nature of the ground, and the short time that one can spend in these inhospitable regions, it would be quite impossible to map the different outcrops of each of the separate groups. Near Lingti the rocks, which I consider as the Carboniferous, are underlaid by a great thickness of hard dark slates, quartzites, sandstones, jaspideous rocks, and the slaty-sandy trappoid rock of the Dras river. These rocks which may be traced across the Báralácha pass into Lahúl, I have also traced to the north-west into the Silurians of Padam and Zangla which rest upon the *gneiss* of the Zánskár range, and continue thence to join the slaty rocks of Dras, to the south-east these rocks are continuous with the fossiliferous Silurians of the Bhabeh pass and Múth.

Speaking of the great slate series at Lingti, Dr. Stoliczka observes[1], "Any one acquainted with the rocks of the Múth series in the *Pín* valley would find all these represented here," and speaks of the lower beds as corresponding with his Bhabeh group (lower Silurian).

Near Lingti the rocks are very horizontal, and the summits of the ranges are capped by shales, blue limestones, and white and purple quartzites and sandstones. Some of these limestones and sandstones seem to me to be probably of Carboniferous age, as they correspond to similar rocks at Pangong, and also to rock specimens in the Indian Museum from the Carboniferous series near Múth: the lower beds are probably, however, upper Silurian, since Dr. Stoliczka found a fragment of an *Orthis* in similar rocks to the west of the Báralácha (Baralatse) pass. The upper Silurians and Carboniferous (Múth and Kuling) in this district and Spiti (as I judge from rock-specimens in the Indian Museum collected by Dr. Stoliczka) seem frequently to be very similar in mineral composition, and it requires a full series of fossils to separate them distinctly. The blue patches on the map in this district must be considered as only approximately of Carboniferous age, they mainly serve to indicate the distribution of the light-colored quartzites and shales on the top of the older slates.

On the Bhága river, some miles below the village of Dárcha,[2] the Silurian slate series is underlaid conformably by distinctly stratified granitoid gneiss[3] which Dr. Stoliczka recognised as his so-called "central gneiss," and which, he says, underlies undoubted Silurians.

This gneiss forms the southern limit of the Ladák and Zánskár basin, but may be treated of here. To the north-west this gneiss is continuous, with the great mass of gneiss of the Zánskár range and Suru, which I described in a

[1] Mem. Geol. Surv. of India, Vol. V, p. 341.

[2] For this area see my map published in the eleventh volume of the "Records," p. 85.

[3] In a previous paper (Rec. Geol. Surv. India, Vol. XI, p. 55) following Dr. Stoliczka, this gneiss was stated to occur at Dárcha itself.

former paper,[1] but which I could not then certainly determine to be the "central" gneiss; according to Stoliczka's identification, this gneiss may now be considered as of pre-Silurian age, and in this district as having been altered out of an older and conformable slate-series, unless some hidden unconformity should exist.

The rocks on the southern flanks of this gneiss ridge will be treated of in the next section, and their general relations in the last section.

## IV.—Rocks of South Lahúl and Kulu.

To the south of the gneiss ridge of Lahúl, we find an ascending series of slates, with a general south-westerly dip. Near the junction of the Chandra and Bhága rivers, we find blue limestones, with carbonaceous shales and a few pale sandstones, capping the slates in the angle between the two rivers. To the south a large mass of the same limestone and other rocks overlies the slates with a southerly dip, and appears to be itself again overlaid by the same slates. The limestones, on a more careful examination, are, however, seen to be folded back on themselves, and it appears probable that they form a synclinal, the slates on the southern side of the synclinal having been bent over and inverted on the limestones: from their physical characters there can be no doubt but that these limestones are the same as the limestones of North Lahúl,[2] which are probably partly upper Silurian and partly Carboniferous.

The Silurian slates of the Bhága and Chandra rivers I have previously traced[3] into Pángi to the north-west, and for some distance to the south-east. Near the village of Kokser on the Chandra there occurs, at the base of an anticlinal in the slate series, some very massive gneiss, which, I think, is in all probability the same as the central gneiss of North Lahúl. This gneiss is overlaid by alternations of gneiss, micaceous rocks and slates, most of which appear to pass directly into the slates underlying the higher limestone, and which would, therefore, seem to be altered Silurians. These rocks continue across the Rotang pass and down the Beás valley nearly to the town of Naggar. Some of the gneiss is very massive, and in many cases seems to overlie the slate-series; this, however, may be due to inversion, and it seems to me probable that some of this gneiss is "central" gneiss, while some has almost certainly been altered out of the overlying Silurian slates. The series is, however, so involved that I was not able to mark out any bands as of a fixed position.

To the south of Naggar we have generally slates and sandstones till we reach the infra-Krol and Krol groups of Mr. Medlicott near Bajoura, which have been already described by him,[4] and to which I shall, therefore, not refer on the present occasion.

[1] Rec. Geol. Surv. India, Vol. XI, p. 53.

[2] In a former paper (Rec. Geol. Surv. India, Vol. XI, p. 54) I thought from their apparently lying among the slates that these limestones formed part of the lower Silurian series.

[3] Rec. Geol. Surv. India, Vol. XI, p. 55.

[4] Mem. Geol. Surv. India, Vol. III, pt. 2, p. 57.

## V.—SUMMARY AND GENERAL CONCLUSIONS.

I now proceed to bring to notice some considerations regarding the general relations of the Ladák rocks to the rocks of the neighbouring Himalaya. In so doing I shall take the rocks in their geological sequence.

1. *The Tertiaries.*—These rocks have been sufficiently treated of in the section devoted to them. I have only to bring to notice the very remarkable resemblance in mineralogical character which exists between these rocks and the corresponding Eocene (Subáthu) rocks of the outer Himalaya. We have good reason to believe that these two groups of rocks were deposited in perfectly distinct basins, and we can, therefore, only conclude that this resemblance in mineralogical characters is due to the Eocenes of both regions having been deposited under very similar physical conditions, and to their materials having been derived from the disintegration of very similar rocks.[1]

2. *The Cretaceous.*—As only small patches of cretaceous rocks occur in the area under consideration, which I have not seen myself, I have no remarks to make concerning them.

3. *The Trias-Jura and Carboniferous.*—The Triassic and Jurassic rocks, with which the Carboniferous are often closely associated, in this area of the Himalaya occupy three main elliptical basins, *viz.*, that of Drás and Tilel, that of Zánskár and Ladák, and that of Kashmír proper, while other outlying masses of the same rocks occur in the Cháng-Chenmo valley, and probably (though the correlation is not certain) in the outer hills. In the western part of the area the Trias and the Carboniferous seem to be very closely connected with each other, and (especially in Kashmír) it is frequently very difficult to distinguish between the two, and, as I have said in my last paper, some of the rocks mapped as Carboniferous may really be Trias, although as the upper beds are unfossiliferous, and of the same mineral character as the lower, except occasionally, it is difficult to distinguish them. No traces of the Jurassic rocks have been noticed in Kashmír or Tilel.

In the Zánskár and Ladák basin, the Carboniferous is very distinct from the Trias, and according to Dr. Stoliczka, there is sometimes local unconformity between the former and the upper groups of the latter: it may be that the lower Trias is represented in Kashmír and Tilel, which would cause the greater union of the Carboniferous and Trias in those districts.

In Spiti Jurassic rocks are extremely prevalent, while, as far as I can judge, they appear to become less and less developed as we approach the north-western extremity of the Zánskár and Ladák basin; Cretaceous rocks are also well developed at the south-eastern extremity of this basin, and are represented only by patches here and there towards the central part. It would thus appear that in the north-western portion of our area the rocks of these basins are older than many of those to the south-east, there being a gradual increase in the proportion of Trias, Jura, and Cretaceous as we travel from Kashmír to Spiti.

The Trias-Jura in these basins is generally characterised by the great pre-

[1] It may possibly be that the Indus and outer Himalayan Eocenes were deposited in two arms of a sea connecting the two to the westward.

valence of whitish dolomites and dolomitic limestones, often locally alternating with poikilitic shales and slates, the relative development of which varies considerably in different districts. The Zoji-Lá slates[1] still remain a puzzle to me, as I cannot correlate them with any of the Ladák rocks, though I still think those nearest the Trias are newer than it, from the evidence of the Panjtarni section. Some of the metamorphic rocks in the centre of the ellipse must, however, I think, be older, though it is extremely puzzling to imagine how they are related to the other rocks, and the country is so rugged and difficult of access that it will be very hard to come to any precise conclusion.

In most parts of Zánskár, Ladák, and Tilel the rocks above the Carboniferous form one continuous geological series, characterised by the great prevalence of dolomites and limestones; except towards Spiti, fossils are very rare, and the whole naturally presents a combined Trias-Jura, as in America. Had no fossils been found in any of these strata, and were geological nomenclature to have originated in this district, the whole rock-series would be classed as one great system.

The great geological unity in many districts of the whole series, from the Carboniferous to the Jura, is a point on which I desire to lay great stress, as indicating the different results arrived at by purely stratigraphical, on the one hand and purely palæontological geology, on the other.

The Carboniferous rocks vary considerably in mineralogical composition: in many parts of the valley of Kashmír they consist of pure blue limestones, full of characteristic fossils; while in other districts of Kashmír and elsewhere, they consist mainly of alternations of shales, slates, and limestones, very frequently containing crinoids and carbonaceous matter, and at other times quite unfossiliferous.

From the occurrence of the Carboniferous and Triassic series generally in synclinal ellipses, with their longer axes coincident with the normal strike of the Himalayan rocks, together with the generally uniform mineralogical character of the Trias, I think it almost certain that these rocks once extended continuously over the whole area.[2] It may be that from the varying composition of the Carboniferous series these rocks were deposited in a shallower sea than those of the Trias.

From the occurrence of no rocks newer than the Cretaceous, and from the vast amount of denudation which must have taken place to remove the Jura and Trias from such large areas, I am greatly inclined to believe that, with the exception of the Indus valley and a band along the outer hills, this area has been land continuously since the Cretaceous epoch.

During the past season I have for the first time had an opportunity of seeing the Krol limestone, and desire to add a few words to my previous conclusions regarding it. It will be remembered that I have described a band of limestone and other rocks running along the outer foot of the Pír Panjál range[3] under

[1] Rec. Geol. Surv. India, Vol. XII, p. 17.

[2] I desire to retract an opinion previously expressed (Rec. Geol. Surv. India, Vol. XI, p. 48) that the Carboniferous rocks were deposited in separate basins.

[3] Rec. Geol. Surv. India, Vol. IX, p. 160.

the name of the Kiol series, which I have regarded as the representative of the Carboniferous. This limestone band I have also considered to be almost certainly, from its composition and position, to be the equivalent of the inverted band of Krol limestone running along the foot of the lower Himalaya in the Simla district, and these opinions I still hold to.

I at the same time considered that the whole of the limestones capping the slates in the Simla district, which are presumed to be the same as the Krol of the foot of the mountains, to be also of Carboniferous age. An inspection of these Simla limestones, with their underlying Blaini rocks and Simla slates, has shown me that they agree so closely with the Carboniferous and Silurians of Lahúl, that I am most strongly confirmed in my opinion that the slates are of Silurian, and at all events the lower limestones, of Carboniferous age. Mr. Medlicott,[1] in describing the infra-Krol rocks, notices in them the great prevalence of a carbonaceous element, and in the overlying Krol, of limestones underlain by quartzitic sandstones. In both these characters the rocks in question agree exactly with the presumably Carboniferous rocks of North Lahúl.

The Krol limestone is, however, so much thicker than the Carboniferous of Lahúl and Ladák, that I now incline to the opinion that the upper part of it is probably the representative of the Trias of those districts. The characteristic dolomite is, however, wanting, and in the absence of fossils we have no means of sub-dividing the Krol. I have already stated my opinion that the enormously thick limestones of Kashmír may be the representatives of both Carboniferous and Trias, and I now extend this opinion to the Simla Krol limestone and the Great limestone of the outer hills. In Kashmír, as I have noticed above, the Carboniferous and Triassic series are generally so closely related that it is often difficult to draw any hard and fast boundary between them, and since they often vary locally to a very considerable extent in mineralogical composition, there would be nothing extraordinary in their being still more indistinguishably blended together in a region some distance away. According to this view the infra-Krol carbonaceous shales would probably be Carboniferous (with which rocks in Ladák they correspond in composition to a considerable extent), and both upper and lower Trias and upper Carboniferous may be represented in the Krol. Some of the shales in the Kiol are much like those of the infra-Krol.

4. *The Silurian.*—The past season's work has rendered an important contribution to the geology of this part of the Himalaya, in confirming the conclusions previously arrived at as to the Silurian age of the great slate series. The key to this problem lies in the Spiti district, where these slates contain Silurian fossils, and underlie conformably the Carbo-Triassic rock series, and overlie the "central" gneiss. From Spiti these Silurian slates may be traced through Zánskár to Drás and thence to Tilel,[2] where I have elsewhere shown that these slates are the equivalents of those of the Kashmír valley, the Pír Panjál and the Kishtwar district. The slates of Pángi,[3] from their relations to the gneiss, must in all probability be of contemporaneous age.

[1] Manual of Geology of India, p. 600.
[2] Rec. Geol. Surv. India, Vol. XII, p. 20.
[3] *Ibid.*, Vol. XI, p. 54.

The slates of Láma-Yuru, Tánkse, the Pangong Lake, and the Cháng-Chenmo valley, from their similarity in mineral composition to those of the Drás river are likewise inferred to be of the same age, which inference is strengthened by the slates of Pangong, which can be traced into connection with those of Tánkse, underlying strata of presumed Carboniferous age.

The slates and gneiss of Rupsu, which likewise underlie Carboniferous strata, must also be placed on the same horizon.

5. *The lower gneiss.*—In the foregoing sketch it has been shown that the gneiss of the Kailás range conformably underlies a large thickness of slates, which seem to correspond approximately in position to the Silurian: following the same system of nomenclature, such gneiss may be termed Cambrian gneiss as consisting of a distinct geological formation. It has further been shown on a previous occasion,[1] that the gneiss of the Zánskár range and of Kashmír is similarly situated in regard to the slates of those districts, which are also classed as Silurian; there is, therefore, considerable *primâ facie* evidence that all this gneiss is contemporaneous.

It now remains to consider whether any or all of such gneiss is equivalent to the "central" gneiss of Dr. Stoliczka. It appears from the sections of the gneiss and Silurians in the Spiti district, where the "central gneiss" was first named, that that gneiss is unconformable to the Bhabeh Silurians, though this is not clearly stated in the text: if this be true, the central gneiss existed as such at the time of deposition of the slates Dr. Stoliczka, however, himself recognised the gneiss of North Lahúl as "central gneiss,"[2] and also suggested that some of the gneiss of the Zánskár range to the south of Padam and Suru belonged to the same formation. No evidence of unconformity can be seen in this section.

It has been noticed in my paper on the gneiss of the Zánskár range[3] that possibly some portion of the latter was gneiss at the time of the deposition of the Silurians; and it was suggested that such gneiss might be the equivalent of the "central gneiss." It was also shown on that hypothesis that the gneiss in North Lahúl identified by Dr. Stoliczka as "central gneiss," must, if rightly identified, be unconformable to the overlying Silurians. But until the conformity or unconformity of the central gneiss is elsewhere settled, it cannot be settled here.

It, therefore, seems pretty clear that the "central" gneiss is represented in the Zánskár range, but, as I have said in my above quoted paper, how much or how little of such gneiss is "central gneiss" cannot be determined. Similarly, in the Kailás range, it is probable, in my opinion, that the lower massive gneiss may be the central gneiss, and therefore unconformable to the higher gneiss beds, if the central gneiss is always so: how much or how little of the central gneiss occurs there I cannot possibly say. As in my other maps, the whole of the gneiss underlying the Silurian slate series has been colored the same tint, and has been called central gneiss; this gneiss must, however, include both the gneiss conformable and that unconformable to the slates (if there be such) and might rather have been called Cambrian and central gneiss.

[1] Rec. Geol. Surv. India, Vol. XI, p. 59.
[2] Mem. Geol. Surv. India, Vol. V, p. 341. Rec. Geol. Surv. India, Vol. XI, p. 59.
[3] Rec. Geol. Surv. India, Vol. XI, p. 60.

The enormous thickness of slates overlying the gneiss in Pángi and in Cháng-Chenmo appears to me to be at least as thick as the slates in the Bhabeh section. It would, therefore, seem on the unconformity hypothesis that such gneiss as conformably underlies the Silurians, and which I call Cambrian gneiss, is unrepresented in that section. How thick or how thin this conformable Cambrian gneiss may be, or whether it is the same as the central gneiss, I cannot say. In other places, where the slate series is thinner, some of the great underlying gneiss series, as I have said in my previous papers, may correspond to part of the Silurians of the Bhabeh section.

I have already stated that the gneiss of the Kailás range dips to the north, and that the oldest beds are consequently exposed along the valley of the Indus: and I have also shown that when the Palæozoic rocks appear along the valley of the Indus beneath the Tertiaries that they are either of Carboniferous or upper Silurian age. We may, therefore, pretty safely conclude that the southern boundary of the Kailás gneiss is a faulted one.

Dr. Stoliczka did not apparently observe the relations of the gneiss of the Kailás range to the overlying slates, and, apparently identifying it with the gneiss of Rupsu, came to the conclusion that all the Ladák gneiss was of Silurian age, a view which in a previous paper[1] I accordingly adopted, before I had personally examined the relations of the rocks *in situ*. This view was, of course, adopted in the "Manual of the Geology of India[2]." With regard to the objection that the Ladák gneiss differs in composition from the central gneiss, I may state that I have elsewhere[3] shown that the gneiss of Drás is frequently granitic in composition, and that there is also a great variety in the composition of the Ladák gneiss, granitic gneiss being not uncommon among the syenitic varieties. The presence of veins of albite granite in the gneiss of the Kailás range in the Chimray valley is another point, as far as it goes, connecting this gneiss with that to the south.

A general survey of the map from north to south shows a series of gneissic ridges (Dhaoladhar, Pir-Panjál, Zánskár, and Kailás) running from south-east to north-west, the hollows between which ridges are sometimes occupied by normally overlying Silurians, and sometimes by newer rocks, which have been faulted down.

ADDITIONAL OBSERVATIONS.

In conclusion, I may add, that I have lately found a series of Carboniferous fossils in the Indian Museum, which were sent by Mr. F. Drew, and were obtained in the Wardwan valley, a little above the village of Súkness.[4] These fossils comprehend the characteristic Carboniferous *Fenestellæ*, *Producti*, and *Spirifers*, and occur in a black shale like that of Eishmakám in the Lidar valley of Kashmir. Some dolomitic limestones, also sent by Mr. Drew from a point still higher up the Wardwan, appear to belong to the Trias.

[1] Rec. Geol. Surv. India, Vol. XI, p. 59.
[2] Page 653.
[3] Rec. Geol. Surv. India, Vol. XII, p. 19.
[4] See map and paper by myself in "Records," Vol. XI. Súkness is about 16 miles north of [illegible].

Near Avantipúr in Kashmír, I found this season some Carboniferous fossils in the higher beds of the trappoid rocks, showing that some of these extend upwards into the Carboniferous.

## TEETH OF FOSSIL FISHES FROM RAMRI ISLAND AND THE PUNJAB, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

### DIODON.

Among the collection of fossils transferred to the Indian Museum from the Asiatic Society of Bengal, there occurs the palatal tooth of a fish, said to have been obtained from Rámri (Ramree) Island, off the Arakan Coast, by Captain Foley. This tooth consists of a series of horizontal and oval plates, lying one above another. Each plate is divided by a vertical line into symmetrical lateral portions, and the lowest plate seems to have lately separated from another inferior plate. Superiorly the tooth is bevelled away by an oblique and concave surface of detrition, exhibiting a section of the edges of each of the component plates. The longer diameter of the lowest plate is 1·2 inches, and the shorter 0·7 inch. The above description will clearly show that the tooth belongs to the genus *Diodon*.

A precisely similar tooth was obtained by Mr. Wood-Mason at Port Blair, in the Andamans, in a sandstone rock.

With regard to the age of the deposits from which these teeth were obtained, it appears from Mr. Mallet's paper on the "Mud Volcanoes of Rámri and Cheduba,[1]" that the author considers the Rámri rocks to be of Nummulitic age: Mr. Blanford, in the "Manual of the Geology of India,[2]" also classes most of the Rámri rocks as Nummulitic, but thinks that some on the eastern side of the island may be of cretaceous age. The rocks of Port Blair, according to Mr. Blanford,[3] are similar to those of the Arakan Yoma, which (p. 713) are also Cretaceous and Nummulitic. From the majority of the rocks in Rámri Island being of Nummulitic age, and from *Diodon* not being known elsewhere below the Eocene, I think it most probable that the fossil teeth are of Nummulitic age.

The living Globe Fishes, according to Dr. Gray,[4] are inhabitants of all the warmer seas, and comprise four species, of which *D. hystrix* alone inhabits the Indian Ocean. Of the latter species I have examined a small specimen, some 10 inches in length. In that specimen the teeth are, of course, much smaller than our fossil specimen, but as the living species grows to a very large size, no distinction can be drawn on these grounds. In *D. hystrix*, however, the worn surface of both upper and lower teeth is quite flat, while in the fossil

[1] Rec. Geol. Surv. of India, Vol. XI, p. 193.
[2] p. 717.
[3] *loc. cit.*, p. 733.
[4] Brit. Mus. Cat. of Fishes, Vol. VIII, p. 306.

tooth this surface is markedly concave. Owing to the difficulty of seeing the teeth in the jaw of *D. hystrix*, I could not institute any closer comparison. I have no opportunity of comparing the teeth of the three other living species with the fossil.

Of the fossil Diodons, *D. tenuispinus*, from the Eocene of Monte Bolca, is a small species,[1] while our fossil is a large one. *D. scillæ*,[2] from the Tertiaries of Southern Italy, seems to have the edges of the plates of the teeth crenulated. The teeth of *D. erinaceus*[3] seem to be unknown. The teeth of *D. vetus*, from America,[4] seem to have had triangular plates. A *Diodon* has been mentioned by Professor L. Adams[5] as occurring in the Miocene of Malta, but has not been specifically named.

Although I cannot be certain of the specific distinctness of the Rámri fossil tooth, I yet think, that as it seems to belong to a distinct species from the species now living in the Indian Ocean, and as it is very difficult to refer to specimens without distinct names, I shall do well if I provisionally call the fossil *Diodon foleyi*, after the discoverer of the Rámri specimen.

On page 35 of the 3rd part of the 1st volume of the IVth series of the "Palæontologia Indica," the Rámri tooth is referred to as of cretaceous age.

The occurrence of the fossil Diodon in the Eocenes around the Bay of Bengal, and the existence there of a living species, would seem to indicate that the genus has inhabited the Indian Ocean continuously since the Eocene.

## CAPITODUS.

The genus *Capitodus* was made by Count Münster[6] for the reception of certain jaws and teeth of fishes from the Miocene of the Vienna basin. These fishes were furnished with palatal, and peculiarly flattened incisor teeth. Count Münster classed them among the Ganoids; but M. Agassiz[7] considered that they belonged to the Sparoid Teleosteans (Breams and Sea-Breams), which seems to be the more probable view. *Capitodus truncatus* has been subsequently described from the Miocene of upper Silesia.[8] I am not aware that any new species of the genus has been recorded since the original five species described by Münster. Some years ago, however, Mr. Wynne sent to the Indian Museum a fish-tooth from the beds overlying the nummulitic salt zone of Kohát, which by Dr. Feistmantel and myself has been determined to belong to the genus *Capitodus*. The tooth is one of the so-called incisor teeth, and has a broad, laterally expanded crown, the dentition of which is worn obliquely and concavely on the inner surface. The external surface is coated with hard shining enamel, and is convex laterally; the base of the crown is anchylosed to a bony pedicle, which must once

1 Pictet: "Traité de Paléontologie," Vol. II, p. 123.
2 *Ibid.*
3 *Ibid.*
4 Leidy: Pro. Acad. Nat. Sci., Philadelphia, Vol. VII, p. 397.
5 Quar. Jour. Geol. Soc., Vol. XXXV, p. 529.
6 Beitrage zur Petrefacten kunde, Bayreuth, 1839—46.
7 Bronn: Index, Paléont. Nomenclator, p. 214.
8 Roemer: "Geologie von Oberschlesien," Breslau, 1870, pl. XLVIII, fig. 4.

have joined the jaw. The width of the crown is 0·7 inch, and its height 0·4 inch.

The general form of the crown of this tooth, and its wear, is much like that of the incisor of *Capitodus truncatus*[1]; the crown is, however, proportionally much wider in the Indian than in the European tooth. The other European species have still narrower incisors. The Indian tooth belongs apparently to a distinct species, which I propose to name *C. indicus*.

The strata from which the tooth was obtained are probably of upper Eocene age. The genus *Capitodus* seems to be closely allied to the living Sparoid *Sargus*,[2] but is distinguished by its broader incisors. The Indian species carries the genus back to the upper Eocene.

## NOTE ON THE FOSSIL GENERA *Nöggerathia*, STBG., *Nöggerathiopsis*, FSTM., AND *Rhiptozamites*, SCHMALH, IN PALÆOZOIC AND SECONDARY ROCKS OF EUROPE, ASIA, AND AUSTRALIA, *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

In my Flora of the Talchir-Karharbari beds, I had occasion to notice what was then known regarding the systematical position of the genus *Nöggerathia*, and also to show the reasons why I thought that certain leaves of the Indian coal beds, described as *Nöggerathia*, differ from this genus in the proper sense; I accordingly named them *Nöggerathiopsis*, leaving them with the *Cycadeaceæ*. At that time I could not refer to the Australian *Nöggerathia;* but later examination and comparison have shown that the Australian leaves, also called *Nöggerathia*, do not generically differ from the Indian *Nöggerathiopsis*, and have therefore to be also classed with this genus.

In India the leaves seem to represent one species only, with about one or two varieties; they are known from (*a*) The Talchir-Kárharbai group, and (*b*) from the Raniganj-Kámthi group.

In Australia this genus is known to begin in the lower coal-measures (below the first marine fauna), from which I described one species as *Nöggerathiopsis prisca*. It is more numerous in the upper coal-measures (Newcastle beds), from which two species of *Nöggerathia* were described by Dana; they should now, of course, be classed with *Nöggerathiopsis*.

There is a close representative of this genus in the Siberian Jura, *i.e.*, in the Kusnezk basin of the Altai, and on the Lower Tunguska (tributary of the Yenissei river). From the former place, two species of *Nöggerathia* were described by Prof. Göppert[3] as *Nögg. æqualis* and *N. distans*, and the formation from which they came was supposed to be Permian.

Quite recently, however, Mr. Schmalhausen has published a short paper on

[1] Münster: *loc. cit.*, Vol. VII, pl. II, fig. 2. Roemer, *loc. cit.*

[2] Owen: "Odontography," pl. XLII.

[3] Tchihatcheff: Voyage dans l'Altai orientale, 1845.

the Jurassic Floras of Russia,[1] where the Flora of the Kusnezk basin on the Altai is described as an undoubted Jurassic flora. Regarding the two mentioned species of *Nöggerathia*, Mr. Schmalhausen says, "The specimens described by Göppert as *Nögg. distans* and *N. æqualis* are apparently leaflets of a *Cycadeous* plant, related partly with forms of *Zamia*, partly with *Podozamites*. The name *Rhiptozamites* is proposed for the same." They are described as very numerous; with them occur *Phyllotheca*, *Asplenium whitbiense*, Bgt., sp. var. *tenue*, *Czekanowskia rigida*, Heer, *Pinus nordenskiöldi*, Heer, *Phönicopsis angustifolia*, Heer, *Samaropsis parvula*. Heer, and also *Gingko*, most of which occur in the Jura of Eastern Siberia and the Amur countries. Of *Cycadeaceæ*, the following were found: *Zamites inflexus*, Eichw., *Podozamites eichwaldi*, and a *Ctenophyllum*.

The genus *Rhiptozamites* is equally numerous on the Tunguska river.

A comparison of the Indian and Australian *Nöggerathiopsis* with the original drawings of the Altai *Nöggerathia* (Göpp. l. c.) shows that they are remarkably close to one another, and the genus *Rhiptozamites*, Schmalhausen, is a Jurassic representative of the genus *Nöggerathiopsis*, which in Australia begins in palæozoic beds, in India occurs in the Talchir-Karharbari and Damuda divisions of the Gondwána system[2] and in Siberia has a close (if not generically identical) representative in Jurassic rocks.

There are now especially three genera: *Phyllotheca*, Bgt., *Glossopteris*, Bgt., *Nöggerathiopsis*, Fstm. (and *Rhiptozamites*, Schmalh.), which begin in Australia in palæozoic rocks, and pass almost unchanged through the subsequent formations into Jurassic rocks in India and Siberia.

In my Flora of the Lower Gondwánas, I shall treat more closely of this genus, where I shall also refer to Count Saporta's recent papers on *Nöggerathia* and various plants included in this genus;[3] as also to some recent observations on the fructification of the Bohemian *Nöggerathia foliosa*, Stbg., which modify to a certain extent the classification given in Mr. Saporta's paper.[4]

## NOTES ON FOSSIL PLANTS FROM KATTYWAR, SHEKH BUDIN, AND SIRGUJAH *by* O. FEISTMANTEL, *Palæontologist, Geological Survey of India.*

### I. JURASSIC PLANTS FROM KATTYWAR.

In 1878, Mr. Fedden, while surveying a portion of the Kattywar peninsula, collected some fossil plants preserved in a friable sandy shale of purplish grey color. They are only very fragmentary, although the fragments are numerous enough; but as a certain interest attaches to them, I think it worth while to name them and discuss, as far as possible, their relations. The plants were found three-quarters of a mile north-west of Than, Northern Kattywar.

[1] Beiträge zur Jura Flora Russlands, 1879. Mélanges physiques et chimiques, Tome XI, tiré du Bull. de l'Acad. Imp. d. scienc. d-St. Petersburg, Vol. XXV.

[2] Permo-Triassic—if the Talchirs are considered as representing a portion of the Permian.

[3] Comptes Rendus des Séances de l'Acad. d. Sc., tome 86, 1878.

[4] While this short note was passing through the press, I received Mr. Schmalhausen's paper with figures, but too late for notice. I shall do so at an early opportunity.

### FILICES.

Group of ALETHOPTERIS WHITBIENSIS, Schimp. (Feistm.) or ASPLENIUM WHITBIENSE, Heer.

There is one pinna of a fern which apparently belongs to this group of fossil plants, but it is one of the more slender forms, and is very closely related to the Jurassic *Asplenium argutulum*, Heer,[1] which also is to be included in the group of *Alethopteris whitbiensis*.

*Alethopteris whitbiensis* is known in India, especially from the Jabalpur and Umia groups; from the latter I have figured a specimen closely resembling that from Kattywar.

### CYCADEACEÆ.

There is only one small fragment, which, I think, belongs to the genus *Ptilophyllum*; it indicates one of the narrow-leaved forms, to which belongs *Ptil.* var. *minimum*, Fstm. from Kach (Cutch); the same was also found in the Sripermatur group of the south-east coast of India.

### CONIFERÆ

Representatives of this Order are pretty numerous, especially leaved branchlets and seeds, although the former in no large specimens. The branchlets appear to me to belong to two species.

*Palissya jabalpurensis*, Fstm. The specimens are a little smaller than the original form from the Jabalpur group.

*Taxites tenerrimus*, Fstm. Several specimens are certainly to be referred to this form of the Jabalpur group.

The seeds are:

*Araucarites cutchensis*, Fstm. These are numerous, of various sizes. They are known from the Umia group, Jabalpur group, and Sripermatur group.

Besides these coniferous plants, there are numerous fragments of long narrow leaves, with a central vein in the better preserved specimens. My belief is, that they also are *coniferæ*, and in this case they most probably belong to the genus *Pinus*, resembling very much *Pinus nordenskiöldi*, Heer.[2]

A comparison of these fossil plants shows that they are related to the flora of the Jabalpur group by the presence of *Palissya jabalpurensis* and *Taxites tenerrimus*, Fstm; while *Araucarites cutchensis*, Fstm. is common to the flora of the Umia and Jabalpur groups. There is also a fern corresponding with a form from Katch and a fragmentary portion of a *Ptilophyllum*. These, with the *Araucarites cutchensis*, Fstm., would correlate this flora also with that of the Umia group in Kach, as was noticed in the Annual Report of the Geological Survey of India for 1878.

[1] Juraflora Ost-Sibiriens, 1876 (Flora fossilis arctica, Vol. IV, 1877), Taf. III, fig. 7.

[2] Beiträge zur fossilen Flora Spitzbergens, Tafel. IX, figs 1-6 (Flora fossilis arctica, Vol. IV 1877); Beiträge zur Juraflora Ost-Sibiriens und des Amurlandes, Taf. IV, fig. 8c (the same Volume), and Tafel. XXII, p. 4, a b., XXVII, 9a XXVIII, fig. 4.

Both these correlations appear (as far as the plant remains show) to be equally justified; and this is certainly of no small interest, as this Kattywar flora thus forms a connecting link between those of the Jabalpur and the Umia groups, placing them, thus, homotaxially on the same horizon. This does not, of course, change anything of well established stratigraphical relations; and there is no objection that the same flora, which if considered from the Jabalpur group only has to be taken as middle Jurassic, should be found in the Umia group with and above upper Jurassic marine animals, and should still retain its middle Jurassic character, which view I maintain.

The case in Kach is, of course, easily solved: the formation is determined from the fauna, although this is associated with a flora of an older facies, but the question becomes more complicated where in the same beds there are found marine animals, of secondary and palæozoic types, as in the Salt-range, and in cases to be described by Mr. Griesbach from the Himalayan Trias.

## 2. NOTE ON SOME PLANTS FROM THE JURASSIC ROCKS AT SHEKH BUDIN (UPPER PUNJAB).

Last year Mr. A. B. Wynne made a collection of fossils at Shekh Budín, comprising a few plant-remains, which, although very fragmentary, are of great importance, as being the first plants collected during the work of the Geological Survey in this northern portion of India. They are, however, not the only plants found in Upper Punjab. Dr. Waagen, in his note on the Attock slates,[1] mentions that there are in the collection of the Geological Society of London several specimens of plants from the Salt-range, although no recognisable specimens were yielded from that ground to careful search by the officers of the Survey.

The plant-fragments of Shekh Budín are preserved in a fine, slightly micaceous shale, of a light purplish-grey color, resembling certain plant-bearing shales of the Jurassic rocks in Kach, but more closely the shales of the Jabalpur group, near Jabalpur. The plants also, as far as determinable, recall those of the Jabalpur group.

The only fossils determinable with some certainty belong to the—

### CYCADEACEÆ.

*Ptilophyllum (?) acutifolium*, Mor.—There is a fragment of a leaf of a cycadeous plant, which belongs to the *Zamieæ* and which I refer to *Ptilophyllum*, for it appears from one of the leaflets that they are not free at the lower angle, but decurring; the upper angle, which is free, is rather a little more rounded than is usually the case in *Ptilophyllum;* but a specimen with very similar leaflets to those under discussion is figured as *Ptilophyllum acutifolium* in my Flora of the Jabalpur group,[2] Plate V, fig. 1.

*Podozamites*, sp.—There is another fragment of a single leaflet, traversed by longitudinal veins. This I refer to the genus *Podozamites*, and it appears to me

[1] Rec. Geol. Surv. of India, 1879, Vol. XII, Pt. 4, p. 184.

[2] Pal. Indica, Ser. XI, 2.

to represent the top portion, as the veins only approach each other without being dichotomous.

An identification of a fragment like this is always more or less uncertain, but in this case I think we can refer the fragment to *Podozamites lanceolatus* var. *eichwaldi*, Heer.[1]

This, although very unsatisfactory palæontological evidence, would so far show that these plant-beds of Shekh Budín have to be considered as representatives of the Gondwánas in the Upper Punjab in association with marine beds—a case like that in Kach, and on the south-east coast of India

### 3. Lower Gondwana plants from the Auranga coal-field.

Mr. C. L. Griesbach, on his way to the Tatapáni and Rámkola coal-fields in Sirgujah, passed through the Auranga coal-field and collected a few fossils from a spot west of Murup, in beds mapped by Mr. Ball[2] as Barakars. Although I could only determine two species, I think them interesting enough for record.

*Trizygia speciosa*, Royle.—The occurrence of this fossil in this coal-field is of interest, as illustrating the geographical and stratigraphical distribution of the species. It was first made known from the Barakars of the Talchir coal-field, where it does not seem to be rare. Subsequently it was found to occur rather numerously in the Raniganj group of the Raniganj coal-field. This Raniganj form appears in general a little larger than that from the Barakars. Later on the same species was brought from the Barakars of the Bokháro coal-field by Mr. Hughes; and it is also known from the Bijori horizon (representing the Raniganj group) of the Satpura basin, in the upper Denwa valley; and now we know of it in the Auranga coal-field from the Barakar group. This species is thus almost equally numerous in the Barakar as in the Raniganj group.

There is no essential distinction between the Raniganj and Barakar forms, both show the characteristic "three paired" arrangement of the leaflets, the same distribution of the veins, etc. The only difference I could find is that already mentioned, between the forms from the Raniganj coal-field (Raniganj group) and Talchir coal-field (Barakar group); but the specimens from the Auranga coal-field (Barakar group) exhibit a size like that of the Raniganj form, so that even this character cannot be used as distinguishing the forms from these two groups, and both must be declared identical.

*Glossopteris communis*, Fstm.—This species is equally frequent through all the sub-divisions of the Lower Gondwanas.

### 4. Fossil plants from the Tatapani and Ramkola coal-fields (Sirgujah).

Last year (1878) a good collection of fossil plants was brought by Mr. C. L. Griesbach from the Tatapáni and Rámkola coal-fields. The fossils are from various localities and from various horizons. Mr. Griesbach, in his forthcoming report on the geology of those coal-fields, indicates the positions of the fossils in

[1] Juraflora Ost-Sibiriens und des Amurlandes, 1877, Vol. IV, p. 109, Pl. XXVI.

[2] V. Ball: Geology of the Auranga and Hutár coal-field (Palamow). Mem. Geol. Surv. of India, Vol. XV, Pt. 1.

each of his sections; it would, therefore, be unnecessary for me to discuss the fossils from each locality; it will be sufficient to speak of the fossils of each group collectively. In this area, the close palæontological relation of the several groups is also clearly illustrated, just as in the Satpura basin, especially, as it appears, between the Raniganj and Panchet groups; for there are fossils from several localities which, according to our present knowledge, correspond more with those of the Raniganj group, while the beds seem to be referable either to this group or to the Panchet group. I shall mention these localities further on.

The most interesting fact illustrated by the fossils brought by Mr. Griesbach is the satisfactory proof of the occurrence of the typical Raniganj group, as it occurs in the Raniganj field. This is shown especially by the numerous occurrence of *Schizoneura gondwanensis*, although, as we know, *Schizoneura* is not entirely wanting in the Barakar group, and is also not very rare in the Panchet group.

BARAKAR GROUP.

I come at once to speak of the fossils of this group, no fossils having been met with in the Talchirs, and also no equivalent of the Karharbári beds. As in the other coal-fields, there is here also no striking palæontological feature characterising the Barákar group, most of the fossils being common to all the sub-groups of the Damuda division, and its presence is with certainty demonstrated only stratigraphically; but a certain negative character can be used, *i. e.*, the absence (or rare occurrence in other cases) of *Schizoneura* (when compared with its numerous occurrence in the Raniganj group) and of certain forms of *Glossopteris*, which I shall mark presently as occurring in the Raniganj group, in which group the genus *Glossopteris* appears to be altogether more numerous.

I first enumerate the fossils from localities which apparently belong to the Barakar group (judged from the stratigraphical position); while at the end I shall mention several localities, about which, from a palæontological point of view, I can form no certain opinion.

1. *Equisetacea.*

*Vertebraria indica*, Royle.—The common form; found on the Sendur river, west of Mitgain; on the Ledho nalah near Karamdiha; between the Mahán river and the Tamor hill, near Majurdaki (southern field).

2. *Filices.*

*Glossopteris communis*, Fstm.—On the Sendur river, west of Mitgain; west of Chumra; on the Ledho nalah, near Karamdiha.

*Glossopteris browniana*, Bgt.—On the Sendur river, west of Mitgain.

*Glossopteris* (*damudica*, Fstm., MSS.)—This is a species which, like *Glossopteris communis*, occurs through the whole of the Damuda series, but is apparently most numerous in the Barakar group and in the iron shales. I have not described it yet, nor has it been figured, but I nevertheless introduce the name, as I shall have to refer to it again when speaking of the Raniganj fossils. From the Sendur river, west of Mitgain; between the Mahán river and the Tamor hill.

*Glossopteris indica*, Schimp.—Between Mahán river and Tamor hill (Majurdaki); north-west of Reonti.

3. *Cycadeaceæ (?)*.

*Nöggerathiopsis hislopi*, Bunb., sp. (Fstm.)—This species, at first known from the Kámthi (Raniganj) group only, was later identified from the Barakar and Talchir-Karharbári groups also. Between the Mahán river and Tamor hill (Majurdaki); Suidud nalah, 1½ mile north of Bheria.

The localities, the fossils of which do not indicate with certainty the Barakar group, are:

(*a*). West of Dhonda, from where I could determine:
*Glossopteris indica*, Schimp, and
*Glossopteris communis*, Fstm.

(*b*). Suknai nálah north of Sarsera: from here I determine:
*Vertebraria indica*, Royle.
*Glossopteris communis*, Fstm.

There is, however, no objection that these localities also should be mapped as Barakar, as is done on Mr. Griesbach's map.

RANIGANJ GROUP.

The occurrence of the Raniganj group in the typical form is, I think, well established in this field by the frequent occurrence of *Schizoneura gondwanensis*, Fstm., and of several species of *Glossopteris*, which hitherto are known from the Raniganj group only; I shall mention them presently; one is already a described form, the others are new.

1. *Equisetaceæ*.

*Vertebraria indica*, Royle, the more branched form, as known from the Kámthi (Raniganj) group; between the Mahán river and the Tamor hill; nalah between Gouri and Ghui; in the Morne river, north of Parasdiha.

*Schizoneura gondwanensis*, Fstm.—Several pieces of shale are filled with specimens of this species, just as is the case in the Raniganj field, and also the shale agrees with that of the Raniganj field. The specimens are in layers, one over the other, preserved as leaved stalks of various sizes and as single leaves. It is additional evidence to the wide geographical distribution and frequent occurrence of this species in the Damuda series, especially in the Raniganj group.

We know this species at present from—

(*a*), the Raniganj group of the Raniganj coal-field, where it is very numerous; from the Jherria coal-field; from the Hingir coal-field; from the Tatapáni coal-field, where it appears to be also numerous; and from the Satpura basin, where it is known from two localities (in the Bijori horizon);

(*b*), from the Panchet group, in the Raniganj field, where it occurs pretty numerously.

(*c*), from the Barakar group on Lumki hill, in the Karharbári coal-field;

(*d*), from the Talchir-Karharbári beds in the Mohpáni coal-field, and (?) from the Talchir shales of the Deogarh field.[1]

In the Tatapáni coal-field it occurs along the nalah at Budatand and near Lanjit.[2]

FILICES.

*Glossopteris angustifolia*, Bgt.; this narrow-leaved form is especially known from the Raniganj group.

Banki Nalah, between Chumra and Gidhi; between Mahán river and Tamor hill; Morne river, north of Parasdiha; Budatand nalah, near Budatand, south of Nowadih; in the Ledho nalah.

*Glossopteris retifera*, Fstm.—This also is a Raniganj form. Banki nalah, between Chumra and Gidhi.

*Glossopt. communis*, Fstm.—Banki nalah, between Chumra and Gidhi; east of Ghui; south of Nowadih; in the Ledho nalah.

*Glossopt. indica*, Schimp., between Chumra and Gidhi.

*Glossopteris*, sp., a peculiarly oval leaf, which, I think, will prove a new species. One specimen of the same kind is known from the Raniganj group of the Raniganj field, and also the rock agrees completely. The net venation is much like that of *Glossopt. communis*, but still finer and narrower, and the midrib diminishes suddenly towards the apex. I shall describe this form in the next fasciculus of the Lower Gondwána Flora North of Meguli (Moholi on map).

*Glossopt. damudica*, Fstm. (MS.)—This species is already mentioned above. Morne river, north of Parasdiha.

*Glossopteris*, sp.—Another species was found in the Tatapáni coal-field, identical with one from the Raniganj field (Raniganj group), not yet described; it is a narrow leaf, with a large net venation, the veins passing out from the midrib at an acute angle. South of Nowadih.

From these fossils, the Raniganj group is certainly quite well established.

There are a few other localities, which palæontologically might be still placed in the Raniganj group, while stratigraphically they seem to be on the Panchet horizon.

*a*. Nalah west of Narola—
*Glossopteris*, sp.

*b*. In the Ledho nalah—
*Glossopteris angustifolia*, Bgt.
*Glossopt. communis*, Fstm.
*Glossopt. indica*, Schimp.

*c*. Near Karamdiha—
*Glossopteris communis*, Fstm.

[1] The specimens appear at least to be *Schizoneura*.

[2] This portion of the Lower Gondwánas near Lanjit is colored as Barákars, the strata being much broken up by dykes, etc., so that no distinction of beds could be made out. The frequent occurrence of *Schizoneura gondwanensis*, Fstm., at this place would refer that portion to the Raniganj group.

These localities thus yield an unusually large number of *Glossopteris*, while in the Panchet rocks, although its occurrence is undoubtedly established, it is only known to occur rarely, and fragmentary. At these localities, however, it occurs in the same manner as in the Raniganj group, and we have either to acknowledge the closest connection of the Panchet and Raniganj groups (which in this field also seems to be shown stratigraphically), or to account for the uninterrupted passage of the Raniganj flora into the Panchet group, in which case the close relation of both is again shown It is, of course, possible that the observations upon which these suggestions are based might be modified by a revision of the survey, but taking the lines as laid down by Mr. Griesbach, we may now say that three-fifths of the species in the Panchet group are those of the Raniganj group.

This mutual relation of the Raniganj and Panchet groups in this field, is so far interesting and important, as at the two last-named localities there occurs a plant which appears to be a *Thinnfeldia*. I shall describe it more closely in my Flora of the Lower Gondwánas

MAHADEVAS.

In succession to the Raniganj-Panchet rocks the Mahadevas are highly developed, as in the Satpura basin; and they have proved equally poor in fossils. Mr. Griesbach discovered only at one locality some fragments of plants, which do not admit of specific determination: one is an *Alethopteris;* the other is doubtful, even as to the genus; it is either a *Tæniopteris* or *Glossopteris.*

The Mahadevas in this area seem to be to the Panchets in the same close relation as in the Satpura basin, where the whole Gondwána system is developed, from the Talchirs (bottom) to the Jabalpur group (top), and these basins where the succession of the several groups is also continuous, are, therefore, of the same interest for the correlation of the various groups

## ON VOLCANIC FOCI OF ERUPTION IN THE KONKAN, *by* GEORGE T. CLARK, ESQ.[1]

I chanced yesterday, in the library of the Athenæum Club, to meet with the two volumes upon the geology of India to which are prefixed your name and that of Mr. Blanford, and in vol. 1, page 327, I lighted upon some remarks very complimentary indeed to myself, but which do not, I think, refer quite correctly to what I advanced, now thirty years ago, on the geology of the western side of the Indian peninsula, in the neighbourhood of Bombay. I therefore address myself to you by letter, and I must ask you to excuse the length into which I may probably be betrayed.

At the time that I reached Bombay in 1844, nothing was known about the origin of the trap of Western India, and I found from Mr. Orlebar, and, I think,

[1] Mr. Clark's observations and views upon the trappean rocks of Western India are much more clearly brought out in the letter (dated 25th July 1879) published above, than in his original papers in the Quarterly Journal Geol. Soc., London, Vol III., p. 221, (1847) and Vol XXV, p. 164 (1869), from which the notice in the Manual was taken. The obscurity upon the important question of denudation is now quite cleared up.—H. B. MEDLICOTT.

from Mr. Malcolmson, both very competent geologists, that even Bombay and Salsette had not been geologically examined, and that little was known of their details and still less of those of the Konkan on the opposite side of the harbour. Feeling much interest in the subject, I determined, while visiting the Island and the main land for other purposes, to pay what attention I could to the geology. I began with Bombay, and spent some time in laying down the dip and direction of its rocks, which I found to be mostly igneous, traps and greenstones, with occasional intervening beds, probably of sedimentary origin, all dipping more or less westward at a high inclination. While thus engaged I was fortunate enough to fall in with a bed, newly uncovered, containing very perfect remains of batrachians, which lay immediately beneath a sheet of basalt capping the western side of the Island of Bombay, and which was evidently its latest formation. I sent home to the late Dean Buckland some specimens of the fossils, which were figured in the Journal of the Geological Society (Vol. III, p. 224), and thus the geological date of the basalt was established. I found the same dip and bearing to prevail in Salsette.

On reaching the Konkan, and pausing near Kalian, I was much struck with the difference between the outline of the eastern and western eminences. The hills of Salsette were sharp-topped and steep, all their lines more or less inclined and covered to the top with vegetation, whereas the hills, or rather mountains, of the Konkan, were flat-topped, their leading lines horizontal or nearly so, their sides terraced, the terraces divided by cliffs, and the tops, at least, bare of vegetation. It seemed as though in the one case the beds, being tilted, had allowed the rain to penetrate and produced disintegration, while in the other, the beds being flat, resisted penetration and its consequences. It was also clear that the eastern mountains, as Towleo, Bhow-mulling, and Matheran, were outliers from the great mass of the Western Ghauts, strictly conformable to them in their structure, and that the dip of their beds, so slight as to appear locally horizontal, was really towards the east, and with a remarkably uniform inclination.

This contrast, obvious at the first glance, led me to suppose that the origin of the traps must be sought for either in the trough of Bombay harbour or in the adjacent margin of the Konkan, or wherever the beds dipped from a centre or central line. It was further evident, with so complete a correspondence between the beds of the outliers and the main range, that the whole must at one time have been continuous, and that a vast mass of intervening matter must have been excavated and removed.

Following out these ideas, I proceeded to examine the floor of the Konkan, at first along its western edge towards Panwell, and then more minutely along a line which pointed westwards from Kalian towards the great bay of the Malsege Ghaut, and which presented some very remarkable appearances.

The rock beds, so far as I observed, at or near the level of the floor of the Konkan, which was not much above that of the sea, were all of a uniform variety of trap, and all amygdaloidal, the vesicles being mostly filled with zeolite. Usually the lower part of each bed was more or less solid, and the upper part vesicular. The vesicles were of all sizes, up to a length of 12 or 18 inches and a diameter of 3 or 4, and they were frequently elongated, as though the trap,

while viscid and full of air bubbles, had flowed in the direction of their longer axis. Occasionally also the vesicles were bent and twisted, as though the trap had flowed over a hard edge, as water over a weir; particulars which seemed to afford a clue to the direction, and in some degree to the circumstances, of the flow. Following upon these indications, I found that I reached a number of hillocks or cones, hollow in the centre, and often with a gap in one side, and within and about these the trap often lay in small streamlets, crossing over or overlapping one another, but all evidently derived from a common source or centre. Frequently these streams had flowed for some distance in parallel lines impinging upon each other, not uniting, so as to leave a V-shaped trough between them, which again was filled up with other streamlets. All these had assumed various shapes according as they had flowed in a trough or over a flat surface, or over an obstacle, or had dropped over some accidental step or fissure in the subjacent rock.

These singular, crater-like, hillocks lay very thick together along the course of the Bervee river above Kalian, and upon that of the upper Kaloo near Bhalook and Kinnowlee. Near the ancient temple of Oombernaut are several, some with a central hollow a quarter of a mile across and sides from 200 to 300 feet high. The interior slope is much steeper than the exterior, and the floor is usually very hard and undulating, as though it had been in a state of ebullition.

Besides those hillocks are also a number of flattened domes very distinct, though of no great height, like huge bubbles of very hard rock, and seen, where the surface is broken, to be composed of layers like the coats of an onion.

These are especially frequent in the upper Kaloo approaching the Malsege. I observed also in the bed of this river, dry or nearly so when I saw it, that in many places it was not excavated as by water, but formed by the parallel junction of two lava streams, the stream filling up which had been dissected out, not eroded, so that the surfaces remained smooth and sometimes almost glazed.

All these appearances led me to believe that I had lighted on a number of foci of volanic or plutonic action, placed along certain lines, and that these were the vents—perhaps sources would have been a safer word—whence the traps of the district, and of the adjacent islands on the one hand and of the Ghauts and Deccan on the other, were derived. I came also to the conclusion, perhaps upon the examination of too limited an area, that the general line of the sources lay nearly north and south down the edge of the Konkan, pointing towards the islands of Heneri and Keneri, and that the line towards the Malsege was a sort of spur or lateral axis, accounting probably for the existence of that very remarkable bay or indentation into the main line of the Syhadree range.

The contrast was remarkable between the irregularity of the streamlets of lava in the plain and near the sources above described, and the excessive regularity of the beds at higher elevation, and at a distance from those points.

This indeed was what might have been expected; a regular and uniform dip being more likely to be arrived at by a lava sheet at a certain distance from its source.

But the above are not the only remarkable features connected with these sources. There are found generally, in the Konkan, large numbers of basaltic dykes, more or less vertical, and usually running in lines straight or nearly so. These are of various breadths, up to 40 feet or even more, and they occur most frequently near the sources or craters described above. Thus there are numbers of them about the Bervee between Kalian and Budlapoor, and they are especially thick between Moorbar and Kinnowlee, and at the head of the Malsege bay, under Sindloo and Hurreechunder. Not only are they found in the floor of the Konkan, but they are seen to cleave the highest eminences of the ghauts, and they extend for some miles in to the Deccan, showing that they were poured out and injected after the great mass of the trap was laid down. It is remarkable also, that though so broad and extended so far as I saw, they are rarely, if ever, connected with any displacement of the intersected beds, or anything like a fault. It is remarkable also that the basalt which in Bombay is spread out as a sheet over the highest of the trap and greenstone beds, also caps the elevations of the ghauts, as may be seen at Khardalla, Beema-Shunker, and other places, though whether these horizontal sheets were caused by the overflow of the dykes, or whether, as is more probable, their material overflowed the craters in the usual way after the trap period had ceased, I could not ascertain. It is, however, evident from the mechanical position of the basalt whether in dykes or sheets, as well as from its relation to the batrachian fossils, that it was thrown up after the trap; and probably both dykes and sheets, though not simultaneous, belong to the same geological period.

The basalt dykes deserve close attention. They are generally vertical, and very rarely magnetic. Also they are almost always composed of small prisms, the axis being at right angles to the course and faces of the dyke. Also they are commonly fringed at each face, the fringe or 'selband' being broken up by vertical planes, parallel to the face of the dyke. The dyke beneath the fort at Kalian is columnar. The basalt is usually homogeneous, though now and then its surfaces are pitted as though small deposits of minerals had been washed out. There is no cohesion between the prisms, so that the dyke is often a mere trough, the matter being removed. Near the Wanaghaut where a large dyke cleaves the nearly precipitous face, the basalt is so far removed that the dyke is represented by a hollow chasm, and forms a steep stair-case, up which is a path for foot passengers.

Although there is no vertical displacement connected with these dykes, the heat of the basalt has hardened and rendered tough the contiguous trap. The effect of this is curious. In the plain near Moorbar the country is intersected by a net work of steep and narrow banks from 100 to 200 feet high, somewhat resembling the junction of a number of lines of railway in embankment. The axis of each of these banks is a dyke, the toughness imparted by which has enabled the banks to resist erosion, while the place of the dyke is marked by a trough a few feet deep, out of which the basaltic prisms, being loose, have been removed

Looking back to the immediate causes of the very peculiar configuration of the

country between the ghauts and the sea, it occurred to me that what I there saw was not unlike what would be seen if the island of Sicily were to be submerged, and Etna be acted upon by water currents. The central part, being shattered, would easily be removed down to the nuclei of the several craters, and the flanks of the mountain being much less shaken would remain and present more or less of a scarp at their innermost and highest edge, and their surface, like that of the Deccan near the ghauts, would be hollowed into ordinary valleys of excavation. If for a single central point one or more lines of action were substituted, the effect would be pretty much what is now seen in the Konkan. Possibly the same effect would be produced by atmospheric action, only in such a case an enormous period of time would be necessary.

Then, as to the contrast between the beds forming the ghauts and those in Bombay and Salsette, the former at a certain distance from the line of action fall with a uniform and gentle slope, whereas the western beds fall at an opposite and much greater dip, and are more or less broken. This I supposed to be due to the previous configuration of the ground. I thought the base of Konkan and the Deccan to be a mass of metamorphic rock, over which the trap flowed at an easy slope, while to the west the same trap flowed into the deep sea. I understand, however, that late researches are opposed to this latter notion, and that there is reason to think that the greater dip of the western bed is due to a subsequent subsidence. This, of course, does not materially affect the question of the common sources of these rocks.

I remark also that the *present*, and I dare say the *correct*, *opinion* is *that these* traps are subaerial and volcanic. I supposed them to be submarine and plutonic, because they seemed to me to have been erupted under immense pressure. This again does not materially affect the leading inferences derived from my observations.

In concluding this long and, I fear, tedious letter, I may be allowed to remark that it is many years since I have paid attention to this or any other geological subject, and that neither formerly nor now have I any pretensions to be called a geologist. I brought home with me a vast collection of samples from every dyke I met with, each labelled with the direction, breadth and leading features of the dyke. I sent these in 1848 or 1849 to the Geological Society, where they were seen by Mr. Horner and the then Secretary Mr. Lonsdale. These gentlemen, however, did not think them worth the space they occupied, and as they declined them, I caused them to be thrown away, nor did I again trouble myself on the subject, until some years afterwards I saw to my surprise my name mentioned in a paper by Mr. Wynne as one of the pioneers in the geology of Bombay.

I am not sorry even now to find or make an opportunity of bringing under your notice as the head of the Indian Survey a sketch of what I did in the field so many years ago. You are necessarily aware of the difficulties attendant upon field work in the Konkan, and will therefore extend to my labours that charity that I suspect they much require.

I add a tracing of a map showing a few of the centres of action, and most of the dykes observed in the Malsego or towards Kalian.

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Two spinel-rubies, with a specimen of the matrix: from the Jagdalak mine.

Major Stewart,
*Corps of Guides.*

Verde antique serpentine, from Shigar, Ladák: it is locally called *Yessham* (jade).

Major Biddulph.

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# RECORDS

OF THE

# GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1880. [May.


## Geological Notes *by* C. L. Griesbach, F.G.S., *Geological Survey of India.*

1. *The metamorphic rocks of the Himalayas.*—It is not my intention to describe here in detail the rocks composing the Himalayas; for this I may refer the reader to the pages of the Manual and the Memoirs. I will only state that I could not see any material difference either in lithology or any other character between the metamorphics of the plains of India and those of the hills. Here as there we have a great deal of gneissic rocks of a porphyritic structure, traversed by many veins of granites of various character, and in that, I may here mention, these rocks reminded me forcibly of the granitic gneiss of the Cape, with its large felspar twin-crystals, to which Hochstetter has long ago drawn attention. Here as there we have folds of metamorphic schists of every lithological variety, traversed by hornblendic dykes, probably old trap outbursts. And both in the Peninsula and the Himalayan chain, the average strike of the metamorphic rocks is somewhere from east to west, and in that also these rocks correspond with the metamorphics of South and Eastern Africa.

When traversing the Southern Himalayas from south to north, two gneissic areas are met with, parallel to each other, and extending more or less along the whole known part of the mountain chain. The first line is in the lower mountains south of the main chain, and in the Kumaun section the Almora hill is a point in that line. Further north is the main gneissic area of the great southern or Indian snowy range, with Nandadevi, Trisul, Mana, and other giants rising far above 24,000 feet. Between and skirting these gneissic lines, a series of metamorphic schists form most of the intermediate ground. In the Kumaun sections, they are found to dip north inside the first range (Naini Tal, etc.), and to pass with the Almora gneiss below the Bageswar limestones; in this formation the dip is rolling, once south, then north again, and finally it appears to pass under the second and great central gneiss area, but in reality the strata form with the latter a great fold, the upper part of which has been removed by denudation. On the other side of the gneissic area the schists re-appear again, reclining on the gneiss, and finally dipping below the old slate formation, which I shall presently prove to be not younger than Cambrian.

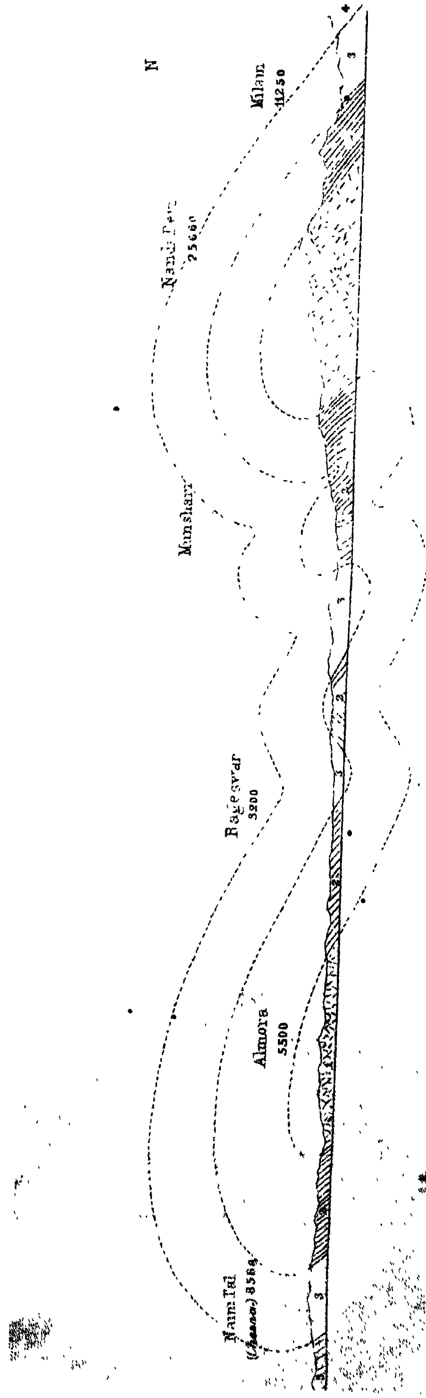



Fig. 1.—Section of the Himalayas between the Tarai and Milam, in natural scale. 1, Gneiss with granite veins. 2, Schists. 3, Cambrian slates and limestones. 4, Silurians. 5, Tertiary series of the Bhábar.

The features may roughly be sketched as shown in the annexed section, in which I have, of course, omitted all the numerous minor folds and a few faults and dislocations which must of necessity occur where such enormous tension existed.

2. *Pre-Silurian rocks of the Himalayas.*—Nearly all sections through the Himalayas reveal on the northern slope and *below* the fossiliferous Silurian series a formation which has often been noticed and always been described as the "Slate series." The lowest member of it is probably a greenish silky and semi-metamorphic slate, seen near Milam to pass into the schists below. But higher up it passes soon into a purple or dark blue quartzite in thick beds associated with beds of a peculiar jasper-like conglomerate, which in some sections forms the lowest bed near the contact with the metamorphics. Not a single trace of fossils has been found in this group, which is very much contorted. It is now crumpled up into a narrow strip, so that its thickness cannot even be guessed at.

Higher beds, consisting of silky greenish slates, quartzites, and lastly, of a dense red quartz-slate, seem at a few places to rest unconformably on the lower group, and everywhere dip below the fossiliferous *Lower Silurian* formation.

A few indistinct traces of Bivalves, and Pleurotomaria? Bellerophon? were found in it. There is very little doubt as to the propriety of classing these last rocks with the *Cambrian* series of elsewhere, on the grounds of their relation to the overlying strata, which by their fossil contents are abundantly proved to belong to the *Lower Silurian system*. The lower group of quartzites and conglomerates may then be termed *Lower Cambrians*; and the whole rests more or

less conformably on the underlying metamorphic series, and shares with the latter in the general folding and disturbance of the strata.

In one or more of the folds of metamorphic rocks shown in the section, fig 1, I found inclosed and folded into a narrow strip a mass of limestones, calcareous conglomerates and shales, here and there silicious, which at once reminded me of the Cambrians of the northern slope of the Himalayas There the conglomerates consisted entirely of quartzites, the same as the cementing matrix, and formed with the latter a very hard jasper-like rock. Here the conglomerates are a hard grey, silicious limestone, pebbles as well as matrix. I believe that the Bageswar limestone really represents a limestone facies of the slate series or Cambrian; and in connection with the folding of the metamorphic series I consider them part of the same marine development of the Cambrians, now severed from the strip north of the central fold by the erosion of the upper arch of the anticlinal

As indicated in the sketch section, fig. 1, I include the Naini Tal (Cheena) limestone for the present in that old Cambrian formation Though the relations of this rock to the neighbouring tertiaries and basaltic traps is not quite clear, it seems best for the present to class them with the Bageswar rocks, with which they have much in common. The Naini Tal beds seem to dip below the metamorphics, but in reality rest above them and merely conform with them in a curve, which, as nearly all the larger ones in this section, have lost the upper arch by denudation, as shown in the above-mentioned section It is needless to state here that the Naini Tal limestone has been compared with the Krol limestone of Simla.

3. *The Pre-Silurian rocks of the Peninsula.*—In Central and Southern India there is found a formation, covering the metamorphics in patches, and in some places overlaid by the Vindhian sandstones. Various are the strata occupying this position between these two rock groups, though mostly silicious, here and there calcareous, with beds of conglomerates, and as yet believed to be wholly unfossiliferous. Last year whilst traversing the Vindhian range on the Sone river, I observed a series of rocks, jasper-like conglomerates, quartzites and grey, almost crystalline limestones underlying the lower Vindhian sandstone near Agori Khas, which afterwards I could not help but compare with the similar rocks of the Himalayas. Here as there they rest directly on the metamorphic rocks.

4. *The Palæozoic rocks of the Himalayas; Silurian to Carboniferous.*—Directly resting on the Cambrian slate series I found a group of rocks as follows:—

*Hanging:* Lower Trias.

| | | | |
|---|---|---|---|
| (About) 350′ | white quartzite with | Carboniferous ... ... | 4 |
| 350′ | red crinoid limestone | | |
| 666′ | coral limestone ... | Devonian? ... . | 3 |
| 1,129′ | quartzite and slates ... | Upper Silurian .. . | 2 |
| 203′ | coral limestone ... | Lower Silurian (Caradoc) ... | 1 |
| 6,573′ | | | |

*Lying:* Upper Cambrian.

I will not now enter into the description of this series, all the beds have proved rich in fossil contents, excepting group 3, which has only yielded a few casts of Orthoceras and a few Corals, which may be either Devonian or Carboniferous. Most of the fossils have already been described by General Strachey, and Messrs. Salter and Blanford. It is an uninterrupted series of beds, passing one into the other almost imperceptibly, but bearing unmistakable fossil evidence, the lowest bed of which, above the Cambrian slates, contains many of the English Caradoc forms, and the uppermost member of which group of rocks (the white quartzite) contains true Carboniferous brachiopods.

5. *Break between Carboniferous and Trias.*—The close of the Carboniferous series marks a great change in the Himalayan area. The next succeeding series of rocks resting on the Carboniferous is the Trias, ushered in by its lowermost member, the *Alpine Werfen beds*, with *all* its characteristic fossils. In some of the sections the contact of the two groups is apparently perfectly conformable, but the absence of the white quartzite in some sections, when the dark bituminous and micaceous Trias-base rests directly on the Red Crinoid limestone, besides the total absence of the Permian group, clearly points to a change of conditions, which must have taken place, at least here, after the close of the Carboniferous epoch. The explanation of this must be sought elsewhere.

6. *The Palæozoic rocks of South Africa.*—Some time ago I had the good fortune to be able to study three great cross-sections through South Africa and part of a fourth, namely –

(1) From Table Bay to the Great Karoo;
(2) From Algoa Bay inland;
(3) From Port Natal to the Drakensberg; and
(4) About 200 miles up the Zambezi on the east coast, but this latter is made very complete by the help of the observations of the late Mr. R. Thornton, the geologist of the first Livingstone expedition, whose extensive journals were placed in my hands by the Royal Geographical Society.

But one of the best sections, and also the earliest described, is the first,—between the Table Bay and the Great Karoo, a distance of about 140 miles. As this one illustrates all the features for comparison with our Indian formations, I will select it for the purpose.

The lowest rock seen is a gneissic and porphyritic granite, which forms the base of the Cape Table-mountain, of the Devils-peak, and Lions-rump. It is seen in several places along the section cropping up with other metamorphic rocks beneath a slate formation, containing fossils. This slate formation probably represents all the lower palæozoic rocks. The great mass of it appears to be of *Devonian* age, proved so by an abundant fossil yield. It is very probable that also the lower palæozoic formations are there represented, as Hochstetter has already hinted at,[1] and recent finds of fossils make this very probable.[2] The whole is very much contorted and rolled up, evidently by a side pressure coming

[1] Dr. F. von Hochstetter: Reise der Oesterr. Fregatte Novara: Geol. Theil., p. 32.
[2] H. Woodward: Quar. Jour. Geol. Surv., 1872, p. 31.

from the south,—the general strike being about east to west or nearly so. Devonian beds with almost the same fossil contents are found in the Falkland Islands, South America.

Quite unconformable on it lie the so-called Table-mountain sandstones. I need scarcely say that, as the name implies, the stratification is almost horizontal, sometimes quite so, thus forming a marked physical feature in the landscape. They are made up of red and brown gritty sandstones, of hard quartzites and partings of silicious shales.

When I crossed the Vindhians last year, I was at once, and forcibly, reminded of the South African tablelands, not only by the similar scarped outlines, but also by the similarity of lithological character.

A few thin seams of coal have been found in the Table-mountain sandstone, and a few badly preserved traces of fossil plants, probably of Lepidodendron, pointing to a Carboniferous age and to fresh-water conditions. As Hochstetter has already pointed out long ago, the Table-mountain sandstone is enclosed between the Devonian formation on one side and the lower Karoo beds on the other; the latter are most likely of Triassic or Permian age, so therefore the age of the Table-mountain sandstone becomes, as a matter of course, Carboniferous.

The close of the Carboniferous epoch marks a great change of conditions here. A steady pressure from the south, which before had already lifted the Devonian deposits above the level of the sea before the deposition of the sandstones, resulted in crushing and faulting of parts of the horizontal beds of the Carboniferous, and a further rise of a fringing southern belt of the Table-mountain sandstone, with a corresponding depression northwards, in which the first deposits of the Karoo series could be laid.

We see therefore that it is with the *close of the Carboniferous that changes of conditions begin, and an entirely new series of forms appear of a decidedly mesozoic type. There is a break,* into which nothing will fit, but perhaps a widely extended boulder bed at the base of the succeeding Karoo beds, and as yet found devoid of organic remains.

7. *The Indian Peninsula during the palæozoic epoch.*—As noticed above, a series of rocks of a semi-metamorphic character occupies in some parts of Central and Southern India the position between the metamorphics on one side and the Vindhian sandstone on the other. These rocks have received many names and are described at length in our Memoirs. Since all are older than the Vindhians, and in some respects analogous with the marine Cambrian deposits of the Himalayas, I may class them together as representing the Cambrian series. With the Cambrians of the Central Himalayas they have this structural character in common, that they share with the underlying metamorphics in all disturbances which have affected the latter both in the hills and in the Peninsula, and that the succeeding formation shows, in places at least, an unconformity. As I have shown above, there is an uninterrupted series of marine palæozoic rocks to be found on the north slope of our Himalayas; not a single member of the marine series is met with south of the central range, and it is fair to assume that the present central range marked the palæozoic boundary between land and ocean, or very nearly so. If my assumption is correct that the pre-Vindhian rocks are identical

with the Cambrians of the Himalayan area, then it is also certain that the change of physical conditions took place near the close of that epoch, and this is proven by the unconformity which marks the junction with the overlying rocks, in the hills the Silurians. Now, assuming that this break after the pre-Vindhian epoch corresponds with the one which occurs after the deposition of the Cambrians in the hills, we further perceive that on one side (Himalayas) we have a great series of marine palæozoic rocks, whereas on the other side (the Peninsula) only a mass of sandstones, quartzites, and shales is found next in succession. From henceforth the physical conditions of the peninsula are those of *terra firma*, and it is beyond doubt that some of the sandstones may represent one or more members of the palæozoic series. It has before been assumed that the Vindhians may be Silurian, perhaps even pre-Silurian, but I argue that the Vindhian sandstones, &c., represent the *whole* of the palæozoic rocks up to the close of the Carboniferous, and that there was not a long continued break between the deposition of the last Vindhians and the lowest Gondwana rocks. Ascending the scale of palæozoic rocks in the hills we find an unbroken series until we reach the close of the Carboniferous rocks, where we find *a break*—Triassic rocks of European type resting directly on Carboniferous. Some disturbances must have taken place to produce this break, changes of physical conditions which must have affected the Indian Peninsula. Now, if we search for the signs of these changes south of the central range, we notice the first unconformity, the first break between the Vindhians and the Talchirs. There is therefore good evidence that the former are simply the freshwater facies of the whole of the palæozoic series and that the Upper Vindhians represent the Carboniferous formation. And indeed this is likely enough if we compare this group with the similar Table-mountain sandstone of the Cape; these two groups not only resemble each other in petrological characters, but occupy relatively the same geological position.

8. *The mesozoic formations in the Himalayas.*—On the Carboniferous in the Kumaun sections, and on older rocks elsewhere probably, we find the mesozoic series ushered in by beds corresponding to the Bunter-Sandstein of Europe, or more correctly to the *Werfen* beds of the Alps. I was able to distinguish the following groups of the Trias and Rhætic[1] :—

| | | | |
|---|---|---|---|
| *Rhætic* | *Avicula contorta* beds ... ... ... | | 2,213′ |
| | Lithodendron-limestone (*Megalodon triqueter*) with several partings of fossiliferous beds, probable representatives of the lower Kössen beds of the Alps ... ... ... ... ... | | |
| | Dolomites with partings of Lithodendron-limestone ... ... | | |
| *Trias* ... | Brown limestones with greenish shales ... ... ... | 782′ | 1,662′ |
| | Greenish shales ... ... ... ... ... | 160′ | |
| | Black limestones, with splintery shales ... ... ... | 488′ | |
| | Grey limestones ... ... ... ... ... | 50′ | |
| | Limestone, earthy ... ... ... ... ... | 3′ | |
| | Campiler, Seisser (Werfen beds) ... ... ... ... | 184′ | |

[1] For a more detailed description and correlation of the Triassic and Rhætic series, I refer to the companion paper in this number of the Records "*Palæontological notes on the lower Trias of the Himalayas.*"

The topmost bed of the Rhætic passes into a thin bed (which is wanting in some sections) containing already Liassic forms, but after that a break occurs. Not a single member of the lower Oolite is found, the only representative of the Oolite (the well-known Spiti shales) contains forms of the upper-middle Oolite. The upper Jurassic beds are quite unfossiliferous dark shales. On them rest cretaceous greenish shales (olive shales of the Punjab ?) and quartz sandstones capped by a white limestone with many cretaceous fossils (Stoliczka's Chikkim limestone).

9. *The mesozoic groups of the Peninsula.*—As already explained in the above notes, we meet with the first great break of deposits of the Peninsula between the upper Vindhians and the lowest Gondwána rocks, a break which I have tried to demonstrate must represent the break which is found between the Carboniferous and the Trias groups of the Himalayan area, and which therefore falls into the Permian epoch, an epoch which, both in Europe and North-Western Asia, represents a passage between the Palæozoic and Mesozoic types of life.

We know that great changes of land and water took place in the Australian region during Carboniferous times, and partly continued during the following periods. Into that epoch fall the deposits of the lower group of beds containing many plants of carboniferous aspect, described by Dr. O. Feistmantel[1] and associated with forms again met with in the shales and silty beds of the Talchirs and Karharbari group, figured and described by the same author. We must assume a disturbance of some continuation and magnitude to explain both the unconformity of the Talchirs on Vindhian and the Trias on Carboniferous series in India; accompanied as it is by an influx of forms belonging to the upper Carboniferous of Australia, it is only fair to assume that a pressure was exerted towards India from the south-east, causing a successive "landwave" to transmit eastern forms of terrestrial life, to travel west and perhaps northward—to India and China.

I believe the direction of this great landwave to have been nearly at right angles with the line of strike of the older north-east wave, which caused the distribution of land and water to change during palæozoic times, traces of which are found in the post-Cambrian both in the Himalayas and the Peninsula.

We see the existence of these two waves clearly exemplified in the present shape of the Peninsula not less than in the long folds of the Himalayas, extending in a north-west to south-east direction across Asia, forming a series of parallel ranges of great elevation, and also in the more or less latitudinal strike of the folds of older rocks of the Peninsula of India and of South Africa, the great river valleys of which two areas indicate this direction by their course. These palæozoic folds are traversed by folds (accompanied by local dislocations), running (nearly) in a north-south direction across the ranges, now deepened by the eroding agencies of glaciers and rivers, and which have shaped the beds of the palæozoic rocks into more or less dome-shaped masses, like so many enormous and inverted cups ranged side by side in the ranges of the Central Himalayas. Not less is it demonstrated by the direction and composition of the Burmese

[1] Palæozoische und mesozoische Flora des östlichen Australiens. In Palæontographica, Suppl. III, Lief. III, Hft. 4, 1879.

chain of hills, where we find Triassic marine beds immediately in rear of the advancing "landwave", which brought mesozoic forms of life to India from Australia.

It is at least probable that the later Carboniferous forms wandered westwards from Australia during Permian times and reached India in that epoch; in the wide basin-shaped folds of the crystallines and oldest palæozoic rocks of the peninsula great inland lakes were depositing material for ages during the whole of the middle and close of the palæozoic times. The same conditions but on an altered surface, still prevailed to a certain extent during the Permian times, for we see the oldest deposits of the incoming period deposited in wide and apparently open basins,- -side by side with the basins of the palæozoic epochs. During the enormous periods of the Triassic and Rhætic times, when huge deposits of marine beds took place in the northern or Himalayan region, the same south-eastern pressure continued more or less, with the result of still more elevating and draining the peninsula, converting the lake-basins into great river valleys, at the same time depressing the Central Asian triassic sea, thus uniting the European (Alpine) with the Armenian (Asia Minor, Caucasus) with the Northern (Siberia) and Southern (Himalayan) basins, the deposits of which all show the most wonderful similarity of animal life which must have existed in those times.

Another link in the chain of evidences in this direction is the continuity of Mesozoic freshwater deposits of South and Central Africa, where we find the extensive Karoo series from the bottom boulder-beds (= Talchirs) to the topping sandstones of the Drakensberg mountains as nearly the same series, and containing similar species of fossil plants and terrestrial animals, as our own Gondwánas. Such an extensive rise of land may well correspond to a widespread triassic ocean extending over the north-western half of Asia and a great part of Europe

After the deposition of the youngest members of the Rhætic or lower Lias, a change in the outline of the great southern continent takes place. Part of the present Indian ocean was formed, and the sea encroached along the western margin of the present peninsula, thus enabling the fluviatile deposits of the upper Gondwánas to mingle with the upper Jurassics of Cutch. Similar changes took place along the southern coast of Africa, *vide* the Jurassics of Uitenhage. Probably the great island of Madagascar is a standing monument of the former extent of the triassic continent of Gondwána-Karoo type. Extensive sandstone deposits fringing the crystalline centre are described to occur in the island.

Indeed, the partial disturbance of post-Liassic times corresponds with the reported overlap of the upper Gondwánas (Mahadevas) over the older Gondwánas, and also with the absence in the Central Himalayan area of the Lower Oolite; on the lowest Liassic beds (which possibly belong really to the upper Rhætics) follow immediately the Spiti shales of upper-middle Oolitic age.

10. *The lower Trias in the marine and in the continental regions.*—Long ago attention was directed to the Triassic deposits of the Alps by the excellent works of the Austrian geologists, being remarkable as containing a singular admixture of Palæozoic forms of life with Mesozoic types. This is especially the case in the oldest Trias beds,—in the so-called Werfen beds, which lately have been divided

again into two sub-groups, both of which I recognized in the Himalayas. These base beds really represent the Buntsandstein of extra-alpine areas, but have a wide extent, being now known over a great part of Armenia, the Caucasus, probably Siberia, and certainly the Tibetan area. In a paper in this number of the Records I give short descriptions of a few new forms of Cephalopods from this bed, along with a fragmentary notice of its fossil contents generally. Besides all the principal fossils characteristic of the Werfen beds of the Eastern Alps, I found associated with them numerous parent forms of Ammonite genera, later on developed in the Trias, and also an undoubted Productus, which most resembles the *Productus latirostratus*, Howse, of the Permian. It is therefore a bed containing an admixture of palæozoic forms with younger types, but the intimate relation with the overlying Trias and Rhætic is well proved by the constant appearance of these variegated shales and limestones at the base of the Muschelkalk, overlapping in succession the various beds composing the Carboniferous formation.

Turning to the Peninsula, we find in like manner the base-rock of the Gondwánas, represented by the Talchirs with Karharbari beds, containing (according to Dr. Feistmantel, who was the first who drew attention to this fact), besides the forms later on so common in the Gondwánas, species closely allied to, if not identical with, the younger Carboniferous plants of Australia. If it is at all possible to compare marine beds with fresh water deposits, then surely the comparison between the "Werfen beds" of the Himalayas with the Talchir-Karharbari beds afford many points of analogy: both are the first deposits which take place after the readjustment of physical conditions in postpalæozoic times, and both contain a mixture of younger palæozoic and of triassic types of forms. I have, therefore, referred both these groups to the same parallel in the annexed table.

11. *The Tertiary series of the Tibetan Himalayas.*—The cretaceous limestones mostly occupy the last range of hills, forming as it were a rim around the vast high plateau of Tibet; beyond is a wide expanse of Tertiary rocks, beyond which appears again the mesozoic section. I only examined the series as far as the Sutlej, which river flows through upper Tertiary deposits.

Leaning against the cretaceous series of the Tibetan passes, I found white and red limestones, with a few indistinct traces and sections of Nummulites, the whole traversed by enormous dykes of a basaltic trap, which has completely altered the rocks into a kind of semi-metamorphic mass, in some parts resembling a porphyry. Stoliczka has described the same occurrence in the north-western Himalayas.

Next follow pepper-and-salt coloured sandstones and grits of molasse appearance, which in all probability represent some member of the southern Siwalik belt. But only here and there the highly inclined lower Tertiaries are seen in the lower river valleys, the whole being covered up by the younger gravels and sands which spread in horizontal beds and widely extended terraces over the great Sutlej valley. I may here mention that in this latter deposit near Dongpa I found fragments of mammalian bones, which makes it tolerably certain that the former finds of bones (Strachey) were also derived from the same source.

It is, therefore, clear that there was a break and change of physical conditions; 1*st*, after the deposition of the Rhætic; 2nd, after the close of the Nummulitic epoch

12. *The Indian Peninsula during the cretaceous and tertiary epoch.*—*a.* The "breaking down" in shoals of the Indian ocean must have continued for a long period; at least the patches of Jurassics and later on of cretaceous beds which penetrated far into the northern half of the Peninsula go far to prove great fluctuations during these times. The presence of remains of a marine cretaceous formation in the south-east of the Peninsula and narrow strips of similar rocks in the Khasia hills, taken in connection with such formation in the Punjab, clearly demonstrates the existence of bays to have existed east and west of the Peninsula during those epochs. It was then that the enormous and long continued pressure coming from the south and now coming from two directions, squeezing as it were the triangular Peninsula forwards and northwards, resulted in the great dislocations of the Himalayan area, which were afterwards developed and widened. The pressure coming from both sides, east and west, resulted no doubt in the bow-shaped outline of the mountain ranges with its convexity near the centre and directed southwards, at the same time dislocating and shattering part of the western limits and thus forming the foundation stones to the later formed Salt-range and neighbouring hills,—west and south-west of the present strike of Himalayan hill-ranges. Simultaneously with this great tension, igneous rocks were pushed up in the dislocations formed; we find such examples in the Silhet Jurassic trap, in the admixture of trappean matter in the Olive-shales of the Salt-range, and the similar trappean-like cretaceous shales and rocks of Tibet.

*b.* The tension must have continued long after the close of the cretaceous epoch and during the deposition of the tertiaries, during which time the enormous dislocations have formed along the Southern Alps,—the west coasts of the Apennine chains, and here, along the greater part of the southern limits of the Himalayas, and lastly along or parallel to the west coast (or somewhere near it), of India,—probably the opening through which the great basaltic flows found an exit, which, both in India and Africa, Arabia and the intervening ocean, play such an important part. Similar to the Mediterranean dislocation, the Indian one is also still the seat of volcanic agency.

It is probable that during the early tertiary times the present Himalayan area consisted of a series of long islands, not unlike the lines of islands now seen in the eastern Archipelago, between which the Nummulitics were deposited; I believe this feature was really owing to a partial breaking down of the area. The basaltic traps which we find in the tertiaries of both sides of the Indian Himalayan axis are met with along the strike of the dislocations.

In the following table I have endeavoured to render the comparison of rocks as above demonstrated :—

*Comparative Table of Indian Formations*

| | HIMALAYAS | PENINSULA | SOUTH AND CENTRAL AFRICA. |
|---|---|---|---|
| | Tertiary fresh water deposits | Tertiary fresh water deposits | Tertiary and recent formations |
| | Break | Break | Break |
| | Nummulitics and trap | Nummulitics and trap | Cretaceous with trap |
| | Cretaceous and trap | Cretaceous and trap (with inter trappeans) | |
| Upper Jurassic | Spiti shales | Mahadevas (Cutch, near coast line) | Sandstones, &c., of the Drakensberg, and Uitenhage Jurassics (coast) |
| | Gap | Overlap | |
| Lias | Lower Lias | | |
| Rhætic | Upper Kossen beds<br>Megalodon limestones, &c<br>Kossen beds<br>Lower rhætic dolomites | Lower Gondwana series (Barakars, Raniganj and Panchets) | Karoo series |
| Trias | Upper, Middle } Trias<br>Lowest Trias (Alpine Werfen beds) | Talchirs | Boulder beds |
| | Break | Break | Break |
| Palæozoic rocks | Carboniferous, Devonian, Lower Silurian, Upper Cambrian } Continuous group of rocks all fossiliferous | Vindhyan series (sandstones &c.) { Continuous group of sandstones, quartzites &c., representing the whole of the post-Cambrian Palæozoic rocks | Table mountain sandstones and quartzites |
| | Partial break | Break | Break |
| | Lower Cambrian slates and quartzites | Lower Cambrian submetamorphics &c. | Devonian (marine), Silurian, slates } much contorted |
| | Metamorphics | Metamorphics | Metamorphics |

## PALÆONTOLOGICAL NOTES ON THE LOWER TRIAS OF THE HIMALAYAS, *by* C. L. GRIESBACH, F. G. S., *Geological Survey of India.*

Major-General R. Strachey, R.E., C.S.I., was the first to notice and describe[1] some of the grand sections through the Himalayas, and to draw attention to the existence in these snowy regions of triassic strata closely allied (as E. Suess has first shown)[2] to the Trias of the Eastern or Austrian Alps. As it has been my good fortune to have been sent to these lofty regions, I must here acknowledge the debt we owe to the learned General for having furnished such an excellent basis for further research in the most interesting region of the globe.

Having mapped the snowy ranges between the valleys of the Dhauli Ganga and Gori Ganga (Niti and Milam), I was able to collect a considerable material for description, but I must defer the detailed report on these noble sections, with maps, until after the next field season, when I hope to extend the survey to the frontiers of Nepál.

The great anticlinal fold of porphyritic gneiss with granite, termed by Stoliczka "Central gneiss" (by way of comparison with the so called "Central gneiss" of the Alps, a definition which has been given up long ago), is conformably overlaid by various metamorphic schists[3] and these again by the Palæozoic and following formations, a brief description of which I have given in the companion paper in this number of the Records. I will therefore only mention that on the eroded surface of the carboniferous rises the huge mass of the triassic and Rhætic strata. The Rhætic beds form high, nearly perpendicular cliffs with an undercliff of older rocks, comprising the whole Trias from the Alpine Werfen beds (Buntsandstein) to the Upper Keuper rocks, all of which are well shown in the natural profile of Plate IV; the proportions of thicknesses and the outlines of the cliff are absolutely correct, being drawn with the aid of a camera lucida, from an opposite height, about in a horizontal plain with the junction of the Rhætic and Trias.

In the following list I give a detailed enumeration of the beds composing both the Rhætic and the Trias, with their probable correlations :—

Upper Oolite (Spiti shales).

| | | Thickness. Ft. | In. |
|---|---|---|---|
| Lower Lias ... | 1. Black shales and dark earthy limestone with oolitic structure, containing ... ... | 13 | 0 |
| Resembles the Grestener beds of the Eastern Alps. | *Belemnites bisulcatus*, Stol. | | |
| | " *tibeticus*, " | | |
| | " sp. | | |
| | *Ammonites annulatus*, Sow. var. | | |
| | " *daysei*, Sow. | | |
| | *Rhynchonella austriaca*, Sss. | | |
| | *Thalassites depressus*, Qu. | | |
| | *Ostrea*, sp. | | |
| | *Pecten*, sp. | | |
| | Total ... | 13 | 0 |

[1] Quart. Jour. Geol. Soc., Vol. VII, p. 292.

[2] Verh. Geol. Reichsanst, 1862, p. 258.

[3] *See* Text illustration, fig. 1, of my paper in this number of the Records, p. 84.

| | | Thickness. Ft. | In. |
|---|---|---|---|
| Rhætic ... | 1. Grey crinoid limestone, very hard, weathering brown, thick-bedded, with intercalated shales, full of fossils, and in many places made up entirely of them. Containing a mixture of true Rhætic and Liassic forms: ... ... | 13 | |
| Represents the Starhemberg facies of Kössen beds of the Alps. | *Pecten bifrons*, Salt. | | |
| | „ *mayeri*, Winkl. (var.) | | |
| | „ *lens*, Sow. | | |
| | „ *corneus*, Gldfss. (non Sow.) | | |
| | „ *cornatus*, Mun. | | |
| | „ *valoniensis*, Defr. | | |
| | *Gervillia inflata*, Schfl. | | |
| | *Plagiostoma herrmanni*, Qu. | | |
| | „ *giganteum*, Qu. | | |
| | *Pholadomya roemeri*, Ag. | | |
| | *Myophoria cardissoides*, Schl. | | |
| | *Cardium rhæticum*, Mer. | | |
| | *Terebratula horia*, Sss. | | |
| | *Rhynchonella fissicostata*, Sss. | | |
| Hauptlithodendron-limestone of Suess: | 2. Grey *Lithodendron* limestone shewing sections of small shells on weathered surfaces ... ... | | |
| | 3. Grey limestone with fossils as bed 1, and *Lithodendron* ... . . | | |
| with Kössen beds in following. | 4. Dark grey sandstone like crinoid limestone with numerous white calcspar veins ... | 9 | 6 |
| | 5. Uneven shaly beds similar to (4) ... .. | 3 | 0 |
| | 6. Dark grey crinoid limestone alternating with shaly beds . . ... | 17 | 0 |
| | 7. Grey massive crinoid limestone .. .. | 17 | 0 |
| | 8. Sandstone-like limestone, false-bedded, here and there shaly ... ... .. | 2 | 0 |
| | 9. Dark brecciated limestone with crinoids ... | 1 | 6 |
| | 10. Very hard grey crinoid limestone with *Lithodendron* ... ... ... | 5 | 6 |
| | 11. Flaggy beds of crinoid limestone . . ... | 2 | 3 |
| | 12. Brecciated bed, made up of angular pieces of dark limestone with a few rounded pebbles; thins out rapidly ... ... ... | 0 | 8 |
| | 13. Crinoid limestone, locally as (12) .. ... | 3 | 0 |
| | 14. Dark crinoid limestone in irregular beds with white calcspar veins ... .. | 13 | |
| | 15. Grey dolomitic limestone in beds of about 1½" alternating with papery shales ... ... | | |
| | 16. Dark grey sandstone-like crinoid limestone, top beds, shaly towards base, in thick masses ... | 16 | |
| | 17. Dark grey flaggy limestone (unfossiliferous) in beds of about 2" to 5", with shaly partings ... | 7 | 0 |
| | 18. Brown shaly sandstone thinning out ... | 0 | 5 |
| | 19. Flaggy limestone, vertically jointed ... | 9 | 3 |
| | 20. Uneven sandstone bed } with thin shaly partings. | 0 | 6 |
| | 21. Grey calcareous sandstone } with thin shaly partings. | 0 | 6 |
| | 22. Grey limestone } with thin shaly partings. | 0 | |
| | 23. Grey calcareous sandstone } with thin shaly partings. | 0 | |

| | | Thickness. Ft | In. |
|---|---|---|---|
| | 24. Grey limestone flags with shaly partings ... | 2 | 0 |
| | 25. „ friable shales .. .. . | 0 | 6 |
| | 26. „ limestone . ... ... | 0 | 9 |
| | 27. Friable grey needle-shales ... ... | 0 | 2 |
| | 28. Grey limestone in massive beds with a few thin partings of shales .. .. | 7 | 0 |
| | 29. Dark grey needle-shales, thin out and pass into limestone .. . .. | 1 | 2 |
| | 30. Thin flaggy limestone beds .. | 0 | 6 |
| | 31. Dolomitic limestone . . ... | 0 | 8 |
| | 32. Shaly limestone . . .. | 2 | 4 |
| | 33. Crinoid limestone with some fossils (Kossen type) | 1 | 0 |
| | 34. Sandy shales ... . | 1 | 8 |
| | 35. Crinoid limestone .. ... . | 0 | 5 |
| | 36 Papery sandy shales ... ... | 0 | 2 |
| | 37 Brown calcareous sandstone (fossils) | 0 | 7 |
| | 38. Crinoid limestone ... . | 0 | 4 |
| | 39. Shaly „ . ... | 1 | 2 |
| | 40. „ and papery calcareous beds ... | 1 | 3 |
| | 41. Grey limestone ... | 0 | 3 |
| | 42. Sandy shales . . | 0 | 3½ |
| | 43 Crinoid limestone . | 1 | 0 |
| | 44. Papery calcareous shales .. . | 0 | 2½ |
| | 45. Sandstone shales ... .. . | 0 | 5 |
| | 46. Shaly crinoid limestone .. . | 0 | 8 |
| | 47. „ and flaggy crinoid limestone | 2 | 0 |
| | 48 Grey calcareous sandstone . .. | 0 | 4 |
| | 49. Shales . ... | 0 | 2 |
| | 50. Grey crinoid limestone ... ... ... | 0 | 7 |
| | 51. Sandy shales . ... ... ... | 0 | 5 |
| | 52. Papery marly shales ... ... | 0 | 10 |
| | 53. Grey limestone with shaly partings ... ... | 0 | 10½ |
| | 54 Friable limestone shales .. . ... | 1 | 0 |
| | 55. Marly bed .. ... ... ... | 0 | 8 |
| | 56. Irregular bed of grey limestone; thins out ... | 1 | 3 |
| | 57. Flaggy limestone with shales ... .. | 6 | 9 |
| | 58. Grey crinoid limestone with *Belemnites* ... | 0 | 5 |
| | 59. Limestone flags with friable shales ... ... | 4 | 0 |
| | 60. Crinoid limestone with *Pecten bifrons*, Salt ... | 1 | 4 |
| | 61. Limestone flags and shales ... ... | 2 | 4 |
| | 62. Shaly calcareous sandstone ... .. | 2 | 9 |
| | 63. Crinoid limestone with a shaly parting ... | 1 | 9 |
| | 64. „ „ with *Pecten bifrons*, Salt ... | 3 | 0 |
| | 65. Dark limestone alternating with shaly crinoid beds | 4 | 0 |
| | 66. „ grey limestone, dolomitic, with shaly partings | 35 | 0 |
| | 67. „ fossiliferous crinoid limestone in massive beds ... ... ... ... ... | 45 | 0 |
| Dachstein limestone. | 68. Grey earthy limestone full of *Myacites* sp. ... | 7 | 0 |
| | 69. Hard limestone beds, containing many fossils, and on the weathered surfaces showing sections of large *Megalodon* sp. ... ... ... | 35 | 0 |

| | | Thickness Ft | In. |
|---|---|---|---|
| | 70. Hard crinoid limestone in thicker beds ... | 7 | 6 |
| | 71. Dolomitic limestone ... . ... | 6 | 0 |
| | 72. " " in flaggy beds ... .. | 3 | 6 |
| | 73. Massive grey dolomite, towards base rather flaggy | 45 | 0 |
| Hauptdolomit ... | 74. " dolomite, with scarcely any bedding ... | 135 | 0 |
| | 75. As (74), but with partings of crinoid limestone .. | 223 | 0 |
| | 76. Dolomite in beds of about 4 feet thickness towards base, reddish, and containing *Lithodendron* ... | 98 | 0 |
| | 77. Dark concretionary limestone with reddish purple cellular Rauchwacke appearance here and there, in beds of 6 inches to 1 foot .. .. | 5 | 0 |
| | 78. Crinoid limestone in thicker beds ... .. | 11 | 0 |
| Plattenkalk of Gumbel. | 79. Dark dolomites in massive beds, the contact surfaces knitted together (resembling sutures, in the outcrop) ... . .. | 100 | 0 |
| | 80. Dolomites and limestone beds with "knitted" contact surfaces as (79), full of *Lithodendron*, and with a few shaly partings ... ... | 18 | 0 |
| | 81 Massive beds of dark blue limestone and dolomite alternating with flaggy beds of limestone; the latter form about 12 feet of the upper part. Some masses of it of dark purple colour with crinoid sections ... .. ... | 50 | 0 |
| | 82. Dark dolomites with calcspar veins .. ... | 117 | 0 |
| | 83. " " flaggy beds and partings of shaly sandstone ... ... .. | 211 | 0 |
| | 84. Dark hard concretionary limestone alternating with dolomitic beds ... ... | 71 | 0 |
| | 85. Grey and reddish dolomites in perfectly inaccessible cliffs, about ... ... . | 700 | 0 |
| | TOTAL ... | 2,200 | 71 |

As I intend to give here only a short description of the lowest members of the Trias, I will only say so much, that in the main the above Rhætic section corresponds exactly with the typical sections of that formation in the Austrian Alps, namely, we have here in descending order :—

1. Lithodendron-limestone, interbedded with limestone containing fossils belonging to the Alpine Kössen beds, which have been grouped into four horizons by Suess=Hauptlithodendronkalk with Kössen beds.
2. Thick-bedded limestones, here and there dolomitic, still with Lithodendrons here and there, and beds with Megalodon=Dachsteinkalk.
3. Great development of dolomites and flaggy limestones=Hauptdolomit with Gumbel's Plattenkalk.

The undercliff consists of a series of beds which represent the whole of the marine Trias beds of the Eastern Alps. The series rests on the denuded and rugged carboniferous quartzites, which again form a steep cliff falling almost vertically down to the base of the valley.

The detailed section of it is as follows:—

| | UPPER TRIAS. | THICKNESS. Ft. | In. |
|---|---|---|---|
| Alps: Opponitzer beds. | ... 22. Compact brown (liver-coloured) limestone, with rough contact surfaces; beds nearly of equal thickness, about 12 inches, and here and there separated by greenish-grey shales. Numerous bivalves, closely allied to ... ... | 152 | |
| | *Corbis mellingi*, Hau. var. | | |
| | 21. Liver-coloured brown limestone, alternating with greyish-green shales, containing . ... | 29 | |
| | *Corbis mellingi*, Hau. var. *Orthoceras*, sp. | | |
| | 20. Earthy limestone with shaly partings ... | 228 | 0 |
| | 19. Shaly limestone with earthy shales alternating ... | 30 | 0 |
| Alps. Lunzer and Partnach beds. | *Spirifer lilangensis*, Stol. var. | | |
| | 18. Shaly limestone and shales with hard concretionary limestone ... ... | 22 | 0 |
| | 17 Greenish-grey shales . . ... | 4 | 6 |
| | 16. Limestone with chert nodules ... ... | 1 | 6 |
| | 15. Flaggy limestone .. ... . | 5 | 0 |
| | 14. Friable greenish-grey shales, weathering brown, with flaggy limestone alternating ... | 31 | 0 |
| | 13. Marly friable shales . .. | 5 | 0 |
| Alps. .. Hallstadt beds. | 12. Hard grey limestone ... .. | 4 | 0 |
| | 11. Hard grey limestone, weathering brown, rather silicious, containing nodules of white concretions with fossils: | | |
| | *Opis globata*, Dtm. | | |
| | *Acrochordiceras spinescens*, Hau. | | |
| | *Tropites ehrlichi*, Hau. | | |
| | var. *Feistmanteli*, n. sp. | | |
| | *Balatonites himalayanus*, Blfd. | | |
| Alps: St. Cassian. | ... 10. Grey earthy limestone beds, with marly and shaly partings, weathers brown. | | |
| | 9. Same as (10) with | | |
| | *Spirigera*, sp. | | |
| | 9, 10, and 11, total ... ... | 275 | |
| | 8. Greyish-green micaceous shales, a few plant impressions ... ... ... | 160 | 0 |
| | 7. Shaly grey earthy limestone ... ... | 38 | 0 |
| Alps: ... Wengen beds and St. Cassian. | 6. Dark splintery limestone flags with dolomitic beds and very scarce partings of black shales ... | 76 | |
| | 5. Black limestone beds in flags of about 6 inches thickness, which form groups of about 8 feet thickness, alternating with the same thickness of black splintery shales, with ... ... | 152 | |
| | a species of the group of the *Amaltheidæ* | | |
| | *Halobia rarestriata*, Mojs. | | |
| | *Daonella tyrolensis*, Mojs. | | |
| | " sp. | | |

| | | Thickness. Ft. | In. |
|---|---|---|---|
| | 4. Dolomitic limestones in more massive beds, with few shaly partings .. ... .. | 38 | 0 |
| Alps . ... Wengen beds. | 3. Shaly limestone with— ... ... *Daonella*, sp. *Spirifer lilangensis*, Stol. var. | 38 | 0 |
| | 2. Thick-bedded shaly limestone with traces of fossils, mostly Ammonites ... ... | 48 | 0 |
| Alps : ... Buchenstein beds. | 1. Black limestone flags of about 12 inches thickness, each alternating with black splintery shales of same thickness ... ... ... | 103 | 0 |

LOWER TRIAS.

| | | | Ft. | In. |
|---|---|---|---|---|
| II. VIRGLORIA LIMESTONE. | *b.* Reifling limestone (Alps). | 122. Very hard grey concretionary limestone in massive beds with subordinate partings of dark shales containing many fossils very difficult to extract: about | 50 | 0 |
| | | *Orthoceras dubium*, Hau.<br>*Trachyceras voiti*, Opp.<br>" *thuilleri*, Opp.<br>" sp.<br>*Arcestes diffissus*, Hau.<br>*Ptychites gerardi*, Blfd.<br>*Pinacoceras floridum*, Wulf.<br>*Pecten*, sp.<br>*Myoconcha*, sp.<br>*Pleurotoma sterilis*, Stol.<br>*Reptilian bones.* | | |
| | *a.* Recoaro-limestone (Alps). | 121. Earthy grey limestone, towards base somewhat shaly: ... ... | 3 | 0 |
| | | *Rhynchonella semiplecta*, Mün., var. " *salteriana*, Stol. } in great numbers. | | |
| I. WERFEN BEDS | *b.* Campiler beds (Alps). | 120. Hard grey splintery limestone ... | 0 | 8 |
| | | 119. Dark friable clayshales, weathering variegated ... ... | 0 | 3 |
| | | 118. Limestone .. ... ... | 0 | 4 |
| | | 117. Limestone with shaly partings ... | 1 | 6 |
| | | 116. Limestone ... ... ... | 0 | 1 |
| | | 115. Shales ... ... ... | 2 | 0 |
| | | 114. Limestone ... ... ... | 0 | 7 |
| | | 113. Shales alternating with 12 thin beds of limestone ... ... | 1 | 0 |
| | | 112. Limestone ... ... ... | 0 | 6 |
| | | 111. Shales ... ... ... | 0 | 4 |
| | | 110. Limestone ... ... ... | 0 | 3½ |
| | | 109. Shales with limestone partings ... | 1 | 2 |
| | | 108. Limestone ... ... ... | 0 | 6 |
| | | 107. Shales, alternating with 11 limestone partings ... ... ... | 2<br>2 | 0 |

| | | | Thickness. Ft. | In. |
|---|---|---|---|---|
| | | 106. Limestone ... .. ... | 0 | 8 |
| | | 105. Shales ... .. .. | 0 | 10 |
| | | 104. Limestone . ... ... | 0 | 6 |
| | | 103. Shales with 5 limestone partings ... | 0 | 11 |
| | | 102. Limestone ... ... ... | 0 | 5 |
| | | 101. Shales ... ... ... | 0 | 7 |
| | | 100. Limestone ... . ... | 0 | 7½ |
| | | 99. Shales ... ... | 0 | 6 |
| | | 98. Limestone ... ... ... | 0 | 7 |
| | | 97. Shales and limestone partings .. | 1 | 2 |
| | | 96. Limestone .. ... . | 0 | 8 |
| | | 95. Shales ... ... ... | 0 | 7 |
| | | 94. Limestone ... ... ... | 0 | 4 |
| | | 93. Shales . ... | 0 | 7 |
| | | 92. Limestone . . .. | 0 | 9 |
| | | 91. Shale with 10 limestone partings ... | 1 | 4 |
| | | 90. Limestone . . .. ... | 0 | 7 |
| | Salt-range: | 89. Shales and limestone partings ... | 0 | 10 |
| | Zone of *N. planulatus*. | *Norites planulatus*, DeKon. | | |
| | DeKon. | 88. Limestone . ... ... | 0 | 6 |
| | | 87. Shales with limestone parting ... | 0 | 1 |
| | | 86. Limestone ... .. .. | 0 | 2 |
| | | 85. Shales with 2 limestone partings . | 0 | 8 |
| | | 84. Limestone . ... . | 0 | 5 |
| | | 83. Shales .. . | 0 | 3 |
| I. Werfen beds.—*contd.* | | 82. Limestone with one shaly parting .. | 0 | 4 |
| | | 81. Shales with two limestone partings | 0 | 6 |
| | | 80. Limestone . .. ... | 0 | 3 |
| | | *Monophyllites wetsoni*, Opp. | | |
| | | 79. Shales ... ... ... | 0 | 5 |
| | | 78. Limestone ... .. ... | 0 | 5 |
| | | 77. Limestone with three shaly partings | 0 | 6 |
| | | 76. Limestone. ... .. | 0 | 5 |
| | | 75. Limestones with 17 shaly partings | 1 | 7 |
| | | 74. Shales ... ... .. | 0 | 2 |
| | | 73. Limestone ... ... | 0 | 6 |
| | | 72. Shales .. ... ... | 0 | ½ |
| | | 71. Limestone ... ... | 0 | 2 |
| | Salt-range: zone of | 70. Shales with ... .. | 0 | 1½ |
| | *Ophiceras lyellianum*, DeKon. | *Ophiceras tibeticum*, n.s. | | |
| | | 69. Limestone .. .. ... | 0 | ½ |
| | | 68. Shales ... ... ... | 0 | 2 |
| | | 67. Limestone ... ... | 0 | 1 |
| | | 66. Shales ... ... ... | 0 | 1 |
| | | 65. Limestone... ... ... | 0 | 1 |
| | | 64. Shales ... ... ... | 0 | 1 |
| | | 63. Limestone ... ... | 0 | 4 |
| | | 62. Shales ... ... ... | 0 | ½ |
| | | 61. Limestone ... ... | 0 | 1 |
| | | 60. Shales ... ... ... | 0 | 2 |
| | | 59. Limestone ... ... | 0 | 3 |
| | | 58. Limestone with 6 shaly partings ... | 0 | 6 |

1. WERFEN BEDS.—*contd.*

| | | Thickness. Ft. | In. |
|---|---|---|---|
| 57. | Limestone ... ... ... | 0 | 2 |
| 56. | Shaly limestone ... ... | 0 | 1½ |
| 55. | Shales ... ... ... | 0 | 1 |
| 54. | Limestone with 2 shaly partings ... | 0 | 5 |
| 53. | Limestone with shales ... ... | 0 | 3 |
| 52. | Limestone ... . ... | 0 | 5 |
| 51. | Shales . ... ... | 0 | ½ |
| 50. | Limestone ... .. ... | 0 | 1 |
| 49. | Shales and limestone ... ... | 0 | 2¼ |
| 48. | Shales .. .. | 0 | 2½ |
| 47. | Limestone ... ... | 0 | 3 |
| 46. | Shales ... ... .. | 0 | 2 |
| 45. | Limestone .. ... | 0 | 2½ |
| 44. | Shales . ... .. | 0 | 1 |
| 43. | Limestone . ... .. | 0 | 3 |
| 42. | Shales with a thin bed of limestone | 0 | 5 |
| 41. | Limestone with 9 shaly partings ... | 1 | 3 |
| 40. | Limestone ... .. ... | 0 | 1 |
| 39. | Limestone ... . ... | 0 | 3 |
| 38. | Limestone with 14 shaly partings ... | 1 | 2 |
| 37. | Limestone ... ... ... | 0 | 2½ |
| 36. | Shales .. ... ... | 0 | 2 |
| 35. | Limestone with shaly partings ... | 0 | 3½ |
| 34. | Shales ... ... ... | 0 | 1 |
| 33. | Limestone with 3 shaly partings ... | 0 | 5 |
| 32. | Shales ... ... .. | 0 | 2 |
| 31. | Limestone ... ... ... | 0 | 2 |
| 30. | Shales .. ... ... | 0 | 3 |
| 29. | Limestone . ... ... | 0 | 2½ |
| 28. | Shales ... ... ... | 0 | 2 |
| 27. | Limestone ... ... ... | 0 | 1½ |
| 26. | Shales ... .. ... | 0 | 1½ |
| 25. | Limestone ... ... ... | 0 | 1 |
| 24. | Shales ... .. ... | 0 | 1½ |
| 23. | Limestone ... ... ... | 0 | 2 |
| 22. | Shales ... ... ... | 1 | 0 |
| 21. | Limestone ... ... ... | 0 | 3 |
| 20. | Shales ... ... ... | 0 | 1 |
| 19. | Limestone ... ... ... | 0 | 3 |
| 18. | Shales ... ... ... | 0 | 4 |
| 17. | Limestone ... ... ... | 0 | 3 |
| 16. | Shales ... ... ... | 0 | 10 |
| 15. | Limestone with shaly partings ... | 1 | 6 |
| 14. | Limestone ... ... ... | 0 | 6 |
| 13. | Shales ... ... ... | 1 | 0 |
| 12. | Limestone ... ... ... | 0 | 3½ |
| 11. | Shales with 11 thin layers of hard splintery limestone ... | 0 | 4½ |
| 10. | Limestone ... ... ... | 0 | 3 |
| 9. | Shales with limestone (1″) towards top with— *Otoceras woodwardi*, n.s. | 5 | 0 |

| | | | Thickness. Ft. | In. |
|---|---|---|---|---|
| I. WERFEN BEDS.—*concld.* | *b.* Campiler beds (Alps). Salt-range, zone of *Ptychites lawrencianus*, DeKon. *Xenodiscus demissus.* „ *gangeticus.* | 8. Limestone ... ... ... | 0 | 2 |
| | | 7. Shales ... ... ... | 0 | 5½ |
| | | 6. Limestone with— ... ... | 0 | 3 |
| | | *Xenodiscus gangeticus*, DeKon. | | |
| | | „ *buchianus*, „ | | |
| | | 5. Variegated papery shales ... | 0 | 6 |
| | | 4. Limestone with— ... ... | 0 | 4 |
| | | *Avicula venetiana*, Hau. | | |
| | | *Myophoria ovata*, Br. | | |
| | | *Posidonomya angusta*, Hau. | | |
| | | *Otoceras woodwardi*, n.s. | | |
| | | *Xenodiscus demissus*, Opp. | | |
| | | „ *gangeticus*, DeKon. | | |
| | | 3. Friable, papery shales with a parting of limestone (1″) with— ... | 0 | 9 |
| | | *Otoceras woodwardi*, n.s. | | |
| | | 2. Dark grey limestone with shaly layers with ... ... | 0 | 5 |
| | | *Posidonomya angusta*, Hau. | | |
| | | *Gervillia mytiloides*, Schlot. | | |
| | | *Modiola triquetra*, Seeb. | | |
| | | *Myophoria ovata*, Gdfss. | | |
| | | *Avicula venetiana*, Hau. | | |
| | | *Bellerophon*, sp. | | |
| | | *Nautilus brahmanicus*, n.s. | | |
| | | *Otoceras woodwardi*, n s. | | |
| | | „ „ var. *undulatum*, n.s. | | |
| | | *Ptychites lawrencianus*, DeKon. | | |
| | | *Ophiceras medium*, n.s. | | |
| | | „ *himalayense*, n.s. | | |
| | | „ *tibeticum*, n.s. | | |
| | | „ *densitesta*, Waag., var. | | |
| | | *Xenodiscus gangeticus*, DeKon. | | |
| | | „ *buchianus*, „ | | |
| | | „ *demissus*, Opp. | | |
| | | *Trachyceras gibbosum*, n.s. | | |
| | *a.* Seiss beds (Alps) Salt-range Productus beds. | 1. Dark, carbonaceous, crumbling shales, micaceous, weathering in reddish and deep-brown tints, giving it a variegated appearance, with a few thin beds of hard grey limestone. The general character of these shales is the same as of all the intercalated beds of shales of the beds above ... | 127½ | |
| | | It yielded— | | |
| | | *Monotis claræ*, Emmr. | | |
| | | *Productus latirostratus*, Howse, var. | | |
| | | *Arcestes* sp. | | |

The whole rests on the carboniferous series.

The above list of beds, it will be seen, corresponds in a marvellous degree with the beds of the Trias as developed in the Eastern Alps, and the order stands therefore as follows:—

*The Trias in the Himalayas.*

| | Character of rocks | Zones. | Correlation with horizons in the Eastern Alps | | Trias in Germany. |
|---|---|---|---|---|---|
| UPPER TRIAS. | 6. Liver-coloured limestone with greenish shales. | *Corbis mellingi*, Hau. var. | Opponitz and Raibl. | | Keuper. |
| | 5. Friable shales and earthy beds | *Spir. lilangensis*, Stol. | | | |
| | 4. Limestone | *Tropites ehrlichi* | Hallstadt and | | |
| | 3. Earthy beds and shales | ... | St. Cassian | | |
| | 2. Black limestone and dolomites. | *Daonella tyrolensis*, Mojs. | Wengen. | | |
| | 1. Black limestone flags and splintery shales. | Brachiopods | Buchenstein. | | |
| LOWER TRIAS. | 4. Hard grey concretionary limestone. | *Ptychites gerardi*, Blfd. | Reifling limestone. | Virgloria limestone | Muschelkalk. |
| | 3. Earthy limestone | *Rhynchonella semiplecta*, Mun., var. | Recoaro limestone | | |
| | 2. Limestone and shales. | *Posidonomya angusta*, Hau. | Campiler beds | Werfen beds. | Buntsandstein |
| | 1. Dark shales, etc. | *Monotis claræ*, Emm. | Beds of Seiss | | |

As far as is known at present, this succession of horizon holds good in India over a considerable area, to judge from certain beds, which have been found in other parts of our Himalayas. The lower group has been described by Stoliczka from the north-west Himalayas (Spiti), but he considered only the upper part of the Lower Trias as such, with *Rhynchonella salteriana*, Stol., and *Ptychites gerardi*, Blfd. He certainly came across the lower group, but in the absence of known Trias fossils he represented it as upper carboniferous, containing numerous *Productus semireticulatus*, Mart. (sp.), *Spirifer rajah*, Dav. I have compared some of his original specimens with my own collection, and have no doubt that the beds are quite identical both in lithological character and probably in their fossil contents.

It might be urged that the presence of the Productus speaks for a Permian age of these deposits; but taking into consideration the fact that stratigraphically the complex of Trias beds is a connected series of deposits without any interruption, with the greyish black shales invariably at their base, the whole resting on

a rugged and denuded surface of the carboniferous quartzite, it must be admitted that on this account alone the shales (Kuling shales of Stoliczka) must be included amongst the Triassic group. These shales resemble the Werfen beds of the Alps, not only in lithological character, but also in the fact that here as there they contain a number of older forms of life side by side with new arrivals. Such is, it appears, the case with the Werfen beds of Armenia[1].

The following forms of the 1st and 2nd groups of the lower Trias are identical with such of the Werfen beds of the Alps:—

*Monotis clava*, Emm.
„ *angusta*, Hau
*Gervillia mytiloides*, Schl
*Modiola triquetra*, Seeb.
*Myophoria ovata*, Gdf
*Avicula venetiana*, Hau

Nearly identical with a Hallstadt form is *Ophiceras* (*Amm.*) *densitesta*, Waag[2]

All the other species represent earlier stages of forms found also in the triassic beds of the Eastern Alps.

So for instance:—

*Otoceras woodwardi* allied to { *Hungarites* (?) *Strombecki*, Griep.
„ *scaphitiformis*, Hau.
„ *zalaensis*, Bökh

*Ophiceras tibeticum*, n. s., allied to *Lytoceras simonyi*, Hau, and other *Lytoceratites*, occurring in the Lower Trias.

## DESCRIPTION OF NEW SPECIES.

### Class CEPHALOPODA.

### Order · TETRABRANCHIATA.

### Family · *NAUTILIDÆ*

### Genus · NAUTILUS.

NAUTILUS QUADRANGULUS, Beyr., *var.* BRAHMANICUS, n. s. Plate I, figs. 1—3.

This species is most nearly allied to the Liassic forms, of which *N. aratus*, Schl., is the representative. The shell is considerably involute, the umbilicus deep. The ventral side flattened, the section of the shell sub-angular. The descent to the umbilicus is vertical and sharply defined. Five radial lines of growth are visible, and a few broad indentations at intervals of about $\frac{3}{4}$ inch along the last chamber indicate a faint kinship of this form to *Nautilus fugax*, Mojs.[3] Towards the mouth the shell opens out, trumpet-shaped. What remains of the last

[1] Abich: Geol. Forschungen in den Kaukas. Ländern, 1st. Theil, Wien, 1878. *See* also Mojsisovic's Verh. Geol. Reichsanst., 1879, p. 171.

[2] Benecke's Geog. Pal. Beiträge, I, p. 369.

[3] Jahrb k. k. Geol. Reichsanst., 1869, Pl XIX, fig. 3.

chamber amounts to exactly one-half of the entire evolution. Siphon situated at about ⅔ of the height (fig. 3). The septa show nearly the same lines as *Nautilus subaratus*, Keys.;[1] the pointed antisiphonal lobe marks this species at once as belonging to the forms of which *N. aratus*, Schl., is the type. The number of septa are about thirty in a whorl.

The only character which distinguishes this species from Beyrich's species *N. quadrangulus*[2] is the fact, that the German Muschelkalk form seems more compressed than our species, so far as I can judge from the figure given. But there can be no doubt that the German Muschelkalk species is a descendant of this lowest Trias form.

Likewise *Nautilus spitiensis*, Stol., is probably also only a later stage of development of this species, which is common in the Werfen horizon of the Tibetan Himalayas.

With the exception of the angular shape of the section of the whorls which is so marked in the Indian species, it agrees very nearly with *Nautilus subaratus*, Keys., both in general shape and course of the lobe line. In fig. 2 I have shown another specimen, which I cannot separate at present from the larger form in spite of the indication of a hexagonal outline of the section of the mouth as shown in the figure. It is probably only a younger individual of the same species.

It is very numerous in Bed 2 (horizon of *Posidonomya angusta*, Hau.) of the lowest Trias

Class: CEPHALOPODA.

Order: ?

Family: *AMMONITIDÆ.*

Tribe: PINACOCERATIDÆ.

Genus: OTOCERAS, n. g.[3]

Amongst the numerous forms found in Bed 2 (horizon of *Posidonomya angusta*, Hau.), one of the most remarkable groups is that for which I propose the above name. Occurring, as they do, in a bed belonging to the lowest Trias, they form the connecting link of a group of forms, the first of which appear in the palæozoic epoch.

The earliest species belonging to the tribe of *Pinacoceratidæ* appear in the Devonian, where we find the *Sageceras sagittarius*, Sandb.

In the Permian of Armenia we find again several species, and representatives of it are found in India (Salt-range) and pass on into Upper Trias, where many species belong to that genus.

The species described under the above generic name appear in the lowest Trias as companions of a number of early Triassic types, in the same bed with

[1] Middendorf's Reise in Sibirien, Pl. IV, fig. 3.

[2] Abh. Akademie, Berlin, Pl. III, fig. 5.

[3] Οὖς, ὠτός = ear.

*Pos. angusta*, Hau. Though it seems that there are several varieties, if not species, amongst the numerous specimens obtained, I prefer to include them for the present under one collective name

OTOCERAS WOODWARDI, nov. spec. Plate I, figs 4 & 5, and Plate II.

Shell involute, with very deep umbilicus, with rapidly increasing outer whorls. The part of the shell nearest the umbilicus bulged out into an ear-like shape, giving the section of the shell (Plate I, fig 4*a*,) a more or less rhomboidal aspect.

It is very probable that the last whorl in adult individuals covered and enclosed the entire shell. In all the specimens which I collected there is a tendency to enlarge the latter whorls at the expense of the umbilicus. The sides of the shell are only slightly curved and slope towards the sharp knife-like siphonal side enclosing an angle of about 67°. The compressed siphonal side is one of the most characteristic features of this species. In one of the adult specimens (Plate I, fig. 4), this part of the shell has quite the appearance of a sharp knife, and only a faint indication of a three-edged termination is visible, whereas in some of the younger specimens (Plate II, figs. 1 and 3) and even in the older form (Plate II, fig 2*a*) the tripartite character of the siphonal side is strongly marked. This character alone would stamp this species as belonging to *Hungarites*, Mojs.,[1] of which *H scaphitiformis*, Hau.,[2] and *H. ·al ensis*, Boekh,[3] are the types, but the shape of the ear-like prolongation of the sides of the shell near the region of the second side-lobes is a character entirely absent in the Austrian genus. A line connecting the ear-like prolongations of the sides, or, in other words, the second side-lobes, will intersect the median plane in a point, from which to the siphonal margin of the preceding whorl is about the third of the entire distance between the point of intersection and the siphonal margin of the outer shell. A vertical projection of the inner margin of the first lateral saddle to the median plane will intersect that plane in the siphon of the preceding whorl.

From Plate I, fig 4*a*, it will be seen that the proportion in the increase of lateral expansion of the last whorl increases rapidly at the expense of the increase to the height of the shell, and it is not at all improbable that, as I said above, the final chamber inclosed nearly the whole of the shell in adult specimens, which character is indicated in fig. 3 of Plate II, which shows the almost vertical sides of the umbilicus, but since drawing the plates I have worked out of some blocks of stone the fragment of a larger specimen, showing part of the last chamber with the umbilicus. The latter is very narrow and closing in towards the outer side. The shell is extremely thick near the ear-like prolongation in the umbilical region and covered with wrinkles. The shell is covered with fine wavy lines of growth S-shaped, slightly bent forward near the siphonal margin.

The lobes show some variation mainly in the auxiliary ones, but these increase in number with the successive whorls in the same specimen. As shown in

[1] Verh. Geol. Reichsanst., 1879, p. 140.
[2] Denksch. Akademie Wiss., Wien, 1855, Pl. III, fig. 4.
[3] A. M. K. Földtani intézet, Pest, 1872, Pl. VII, figs. 1 and 2.

the drawings of lobes in Plate II, this species possesses a broad siphonal lobe ending on both sides of the semicircular siphonal saddle in a sharp point. The external saddle (fig. 1*b*) is moderately high and a little narrower than the siphonal lobe. The first lateral lobe is the deepest of all, of the same width as the external saddle, and at the base shows plainly a tripartite arrangement of the serration.

I remarked also that the corresponding lobes vary on each side of the specimen (fig. 1). Whilst the first lateral lobe of the left side shows plainly this tripartite arrangement of serration, those on the right side have an additional sharp point added to the lower margin of the lobe as shown in fig. 1*b*. The larger specimen, fig. 4, shows a still more complicated serration of this lateral lobe, similar also in figs. 3 and 5. There follows in all specimens a very large first lateral saddle, slightly bent towards the inner side, with following rather narrow second lateral lobe, serrated at the base, this serration varying in the different specimens. The second lateral saddle is only half as high as the first and great lateral saddle, rather wider in proportion to its height, and followed by one or two auxiliary lobes of varying course. In some specimens the first auxiliary lobe reaches only half down the rounded and broad second lateral saddle and is not serrated at the base and might be described as a rudimentary lobe; in others, figs. 2*b*, 4 and 6, the auxiliary lobes and saddles are similar in shape to the last lateral lobe and saddle, decreasing in size as they near the ridge (r), noticed above. Beyond this the sutural line runs in a series of rudimentary lobes and saddles to the sutural margin (s), where it forms a flat serrated lobe; on the antisiphonal side I noticed on prepared specimens (fig. 6) a saddle, as broad as high, sloping towards the margin (s) followed by a narrower but deeper lobe, serrated at base, and a second higher and wider saddle, similarly sloping towards the marginal side. The antisiphonal lobe is bipartite.

*Locality*.—South of Rimkin Paiar and north of Kiunglung encamping ground, head-waters of the Ganges river.

OTOCERAS WOODWARDI, var. UNDATUM, n. s. Plate I, fig. 5.

With the first described specimens and only at one locality were found a few individuals agreeing in general shape and lobes with *Otoceras woodwardi*, but, unlike even the larger specimens of this species, showing very marked wavy ribs, only very slightly bent forward near the siphonal margin, but swelling out near the middle of the side of the shell. As none of the other specimens show this character, I have thought best to separate it for the present as a variety of the other form.

*Locality*.—South of Rimkin Paiar, east slope of the Kurgudthidhar mountain.

*Allied forms*.—The ancestors of the forms above described must be sought for in the family of the *Pinacoceratidæ*, Mojs., the oldest known ones of which occur in the Devonian of Oberscheld, *Pinacoceras sagittarius*, Sandb.[1] That *Sageceras*, known from the Permian and which like *Pinacoceras* lived up to the

[1] Sandberger: Schichtensystem in Nassau, p. 77.

Upper Triassic times, is a descendant from *Pinacoceras* is probable. There is another form which bears close resemblance to *Otoceras*, *Goniatites intumescens*, Bey.[1] var. *acutus*, which is a close relation of it and belongs to the Devonian system. In external shape, thickness of shell, fine lines of growth and the sharp-edged siphonal margin, they are all but identical, and from the figure (1*a*) it seems as if this species also, in a rudimentary stage, possessed the ear-like prolongations of the shell near the umbilical region. Turning to the lobes we find also the first lateral saddle largely developed and turned towards the umbilicus, and an indication of a second lateral saddle, but the lobes terminate in simple sharp points only, though corresponding in general proportion. The line of projection of the preceding siphonal margin (vertical to the median plane) cuts through the second lateral lobe near the inner margin of the great first saddle. We have here the true predecessor of *Otoceras* in Devonian beds.

The next younger form known is *Hungarites* (*Ceratites*) *strombecki*, Griep.[2] from the lowest Wellenkalk of Brunswick, which shows many characteristics of my genus, but most so in the form of the lobes (fig. 3) which are nearly identical with mine. Apparently also the projection of the siphonal margin of the preceding whorl passes through the second lateral lobe.

Whether the genus *Hungarites*[3] is a further development of *Otoceras* is not quite clear to me, but the description of the lobes given by J. Böckh[4] seems to point to a relation with the older form of *Otoceras*. Mojsisovic[5] hints at the possible derivation of *Pinacoceras* from *Goniatites emaciatus*, Barr.,[6] and indeed this species shows even greater likeness in general form and arrangement and position of the lobes to *Goniatites intumescens*, Bey., so that there is the indication of a pedigree, which would stand thus:

| | | | |
|---|---|---|---|
| Silurian ... ... ... | | *Goniatites emaciatus*, Barr. | |
| Devonian— | *Pinacoceras sagittarius* | | *Gon. intumescens* |
| Carbons. and Permian— | *Sageceras* | | |
| Werfen beds— | | | *Otoceras* |
| Lower Wellenkalk— | *Carnites* | *Norites* | *Hungarites* |

[1] Sandberger's Verst. Rhein. Schichtensyst., Taf. VII, fig. 1.
[2] Zeitsch. Deutsch. Geol. Gesellsch., Taf. VII.
[3] Verh. Geol. Reichsanst., 1879, p. 140.
[4] Földtani intézet, 1873, p. 156.
[5] Abh. Geol. Reichsanst., Bd. VI, p. 43.
[6] Syst. Sil., Vol. II, Pl. III.

PTYCHITES LAWRENCIANUS, DeKon.: Quart. Journ. Geol. Soc., Vol. XIX. Pl. VI, fig. 3.

As such I determine a few not well preserved specimens. They agree very well in general shape and in the formation of lobes with the Salt-range species, but with this exception, that my specimens exhibit traces of an ear-like ridge near the umbilical margin, thus showing some kinship to *Otoceras woodwardi*. Further researches in the Himalayas may reveal better specimens.

Of older forms the most nearly allied are *Goniatites hœninghausi*, Von Buch,[1] *G. intumescens*, Bey., var. *intermedius*, Sandb.,[2] and *G. buchii*, Vern.,[3] thus showing in some degree a derivation from the early types of *Otoceras*, and itself representing a predecessor of the later *Ptychites* forms of the Muschelkalk.

Genus: NORITES.

NORITES PLANULATUS, DeKon., var.: Quart. Journ. Geol. Soc., Vol. XIX, Pl. V, fig. 1.

My species differs somewhat from DeKoninck's figure, in that the ribs on the sides of the shell are more strongly marked and seem indeed to form tuberculous masses; the siphonal part is perfectly flattened, and resembles in that *Norites gondola*, Mojs. This species is common in the higher beds (89) of the Campiler group of the lower trias.

There is an excellent predecessor to this species found in *Goniatites tenuistriatus*, Vern.[4]

Tribe: **LYTOCERATIDÆ.**

Genus: OPHICERAS.[5]

Under this generic name I propose to unite forms which possess the external characters of the *Lytoceratidæ*, but possess a much simpler lobe-line even than *Monophyllites*, and must be considered as an older stage of development of the *Lytoceratites*, which appear first in the Muschelkalk. For the description of the generic characters I refer to *Ophiceras tibeticum* n. s., which may be looked upon as the type of my genus.

OPHICERAS TIBETICUM, n. sp. Plate III, figs. 1 to 7.

Shell compressed, section of whorls oval and widening near the umbilicus (see figs. 2 and 3); the latter large and shallow. The shell with seven to nine whorls, each covering a little more than a third of the preceding one. The shell is thick, especially so near the umbilicus, and covered with fine wrinkles or lines of growth S-shaped and bent forward near the siphonal side (figs. 4 and 5) In the body-chamber, they assume the character of fine S-shaped ribs (fig. 6), resembling in that stage the ribs of *Lytoceras simonyi*, Hau., with which species my form corresponds in many characters. At irregular intervals the shell swells into rounded bumps, largest near the umbilical margin. The siphonal side is rounded,

[1] Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXV, fig. 7.
[2] Rhein. Schicht. Syst., Pl. VII, fig. 2.
[3] Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXVI, fig. 1.
[4] Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXVI, fig. 7.
[5] Οφις = serpent.

and the wrinkles or folds run across it and join with those of the other side. In a larger fragment of a body-chamber, which I refer to this species (fig. 1), the back is smooth, and the wrinkles or folds show only near the umbilical side.

The lobes are simple; the projection of the preceding whorl intersects the second lateral lobe near the outer wall of the second lateral saddle; the siphonal lobe is much wider than high, with a moderately high siphonal saddle, separated by the siphon. The external saddle is about as high as wide. The first lateral lobe is very deep and narrow, followed by a high first lateral saddle, bent inwards. The second lateral lobe is narrow and reaches only half as low as the first one. The second lateral saddle resembles in shape and height the first one, followed by a lobe of about the same depth as the last one, situated at the umbilical margin. The internal sutures are very simple. A deep bipartite antisiphonal lobe is accompanied by a rounded low saddle on each side. The margins of all the saddles are entire and the arches of the lobes very finely serrated, and in younger specimens and the inner whorls of others, often entire. Some fragments of young individuals resemble in general shape this species, but show slight deviations in the lobe-line (fig. 7).

Both in general shape and number, and arrangement (though not shape) of the lobe-lines, this species closely resembles the Lytoceratite genera (*Monophyllites* and *Phylloceras*) of the Muschelkalk and Hallstadt respectively, and may be said to be an earlier stage of these forms.

The earliest appearance of a form belonging to the chain of which the above species is only a link may be said to be *Goniatites bohemicus*, Barr., from the Silurian, and can be traced through a variety of allied species to the Devonian of Nassau, where we find in *Goniatites æquabilis*, Beyr., an exact likeness of our Himalayan species. Both section of shell[1], general characters and striation, agree perfectly, and there is a strong resemblance even in the lobe-line. The external saddle is rudimentary, as is also the second lateral saddle, which is moved nearer the umbilical margin. But there, as in our species, we find a strongly developed and large first lateral lobe, with a bend towards the inner side, closely resembling the later Himalayan species. We have here connecting links of a long chain of forms beginning already in Silurian times and reaching probably high up in the cretaceous series, thus:

Silurian: *Goniatites bohemicus*, Barr., etc. etc.

Devonian. *Goniatites æquabilis*, Beyr.

Lower Trias: *Ophiceras*, etc. etc.

Muschelkalk: *Monophyllites.*

Hallstadt: *Phylloceras.*

etc. etc.

[1] Sandberger's Rhein. Verst., Taf. VII, fig. 10.

OPHICERAS HIMALAYANUM, nov. sp. Plate III, fig. 8.

Shell rather less evolute than in the last described species, the last whorls rapidly increasing in height, and in that resembling more the *Lytoceras simonyi*, Mojs., even than the last species. But both the sculpture of the shell and the lobes differ considerably from *Ophiceras tibeticum*. There are a number of nearly straight, only sightly S-shaped, ribs running across the sides of the shell, which near the commencement of the body-chamber (indicated by a small arrow in fig. 8) almost disappear and change into irregular fine wrinkles and bumps near the umbilical side. What remains of the body-chamber is about one-half of the entire whorl. The siphonal side is rounded, the umbilical margin sharply defined, descending straight down towards the shallow and wide umbilicus. The lobes are identical with those of the following species (figured in fig. 9*b*).

OPHICERAS MEDIUM, nov. sp. Plate III, fig. 9.

General proportions of the shell the same as those of the last described species, but the shell is nearly smooth and only shows slight radiating wrinkles, which disappear entirely towards the siphonal side and are only slightly bent forward in that region. The lobe-line, fig. 9*b*, resembles more that (fig. 7) which I considered as a younger individual of *tibeticum*, n. s. The siphonal lobe ends in two sharp points on each side of the divided siphonal saddle; the external saddle is a simple arch, rather wider than high, followed by a narrower, very finely serrated (at the base) first lateral lobe. The first lateral saddle is wider than high and bent towards the umbilical side. The second lateral lobe does not reach so far down as the first, is narrower, but also very finely serrated at the base. The second lateral saddle is low and broad, and reaches over the umbilical margin; on the antisiphonal side I noticed a deep and bipartite antisiphonal lobe with a rounded saddle on each side connected with the second lateral saddle by a finely serrated lobe-line, representing one or more auxiliary lobes.

MONOPHYLLITES WETSONI, Opp., Pal. Mitth. Plate LXXXVI, fig. 2.

Agrees well with Oppel's figure, both in outward appearance and course of lobe-line. It was found only in fragments, but is very common in the upper beds of the lowest Trias group—the Campiler beds of the Alps.

TRACHYCERAS (?) GIBBOSUM, nov. sp. Plate III, fig. 10.

With the above forms occurs an Ammonite, which in outline resembles somewhat *Trachyceras (Amm.) semipartitum*, Von Buch[1], but the latter is involute in a higher degree than my species, and consequently developes several auxiliary lobes which are wanting in our species. I have at present referred this form to *Trachyceras*, but it is very probable that it represents a connecting link between *Ophiceras*, n. g., and *Xenodiscus*, Waag., as exemplified in *X. gangeticus*, DeKon., and *Buchianus*, DeKon., which I venture to include in Waagen's new genus.

[1] Über Ceratites Akad. Wiss., Berlin, 1849, Pl. III.

*T. gibbosum* is moderately involute, leaving a wide and shallow umbilicus; the shell is thickest, near the middle of the sides, in the region of the "bumps," which occupy exactly the centre-line of the sides, and are about six in number in the last whorl. The inner whorls are quite smooth, and on the surface of the shell itself neither ribs nor striæ are visible. The section of the mouth is oval, widest about halfway up the sides. The siphonal side is perfectly rounded. The body-chamber, as far as it is preserved, amounts to about half a whorl (the arrow indicates the commencement of it, fig. 10).

The lobes are very simple and resemble those of *Ophiceras medium*, n. sp., and partly also those of *Trach. semipartitum*, v. Buch. Besides the low siphonal lobe there are one external and two lateral lobes with one auxiliary lobe, which is situated near the umbilical margin. The antisiphonal lobe is deep and ends in two minute points (fig. 10*b*).

## Tribe: **AEGOCERATIDÆ**, Waag

### Genus: XENODISCUS, Waag

#### Xenodiscus demissus, Opp.

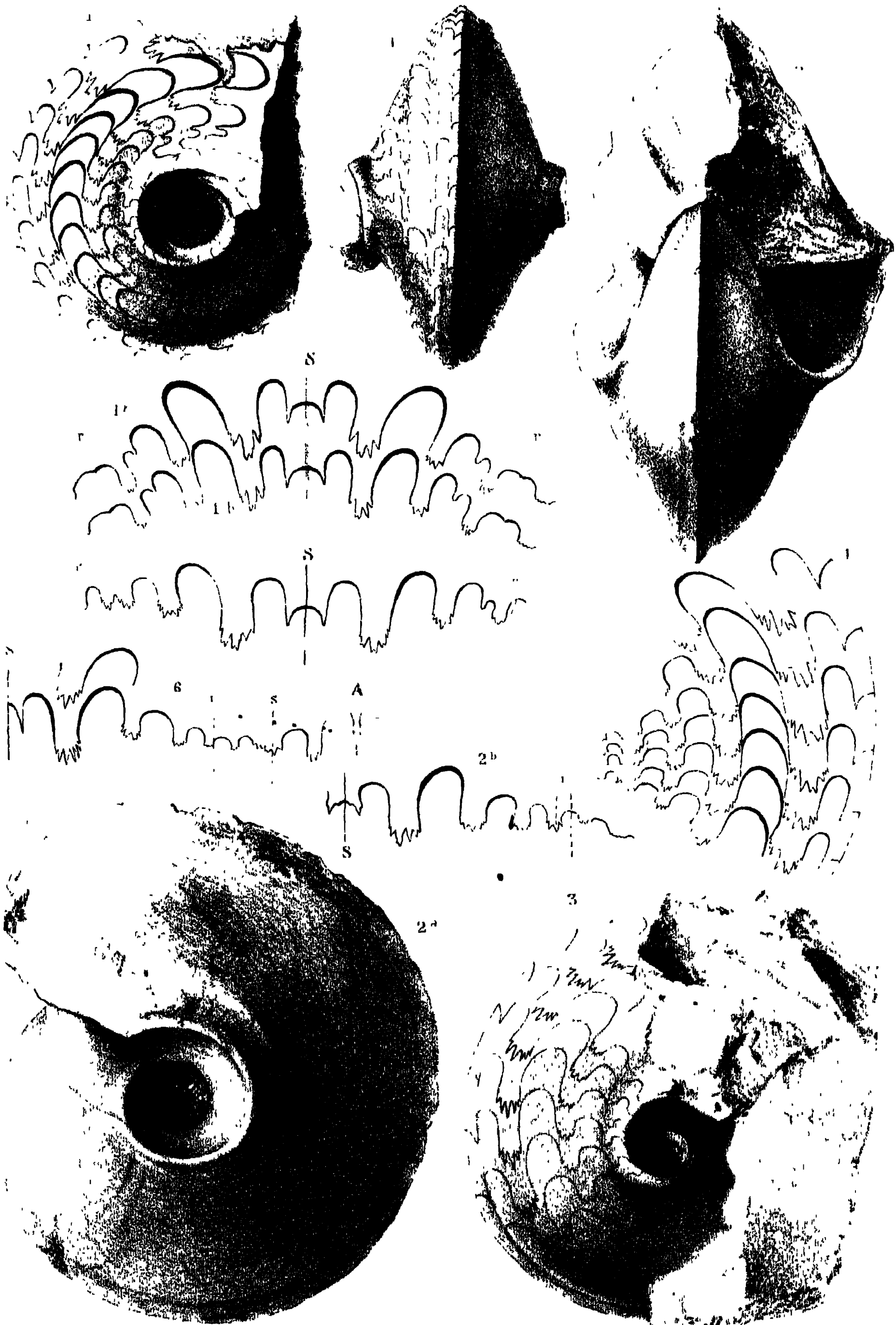
1862. *Ammonites demissus*, Opp.: Pal. Mitlh., Taf. 86, fig. 1.
1872. *Ceratites carbonarius*, Waag.: Mem. Geol. Surv., India, Vol. IX, Pl. I, figs. 2 & 3.
1879. *Xenodiscus carbonarius*, Waag.: Palæont. Ind., Ser. XIII, Pl. II, figs. 2 to 5.

With the species above described and in the same bed (2) with *Posidonomya angusta*, Hau., and other Werfen bed fossils, occur numerous specimens belonging to a chain of forms which might be roughly described as beginning with the flat and characteristic *Xenodiscus demissus*, Opp., and ending with *Xenodiscus (?) buchianus*, DeKon.

I have nothing to add to the description of the above-named species after the excellent exposition given by Waagen in the Palæontologia Indica, but may add, that there can be no doubt that Oppel's figure agrees with Waagen's species, as it does with my specimens. The species is so common in bed 2, that necessarily there is a great variety of forms, all, however, agreeing in the principal characters. They show greatest variation in the ribs or wrinkles of the shell, to which I may add that the shell itself is rather thick, especially so half-way up the flattened sides, and is covered by wrinkly lines of growth, which at intervals develope into ribs.

It is possible to arrange from amongst them a complete chain, passing from the evolute specimens (representing Oppel and Waagen's species) up to considerably involute varieties, and in that stage closely resembling the two species of DeKoninck's *Goniatites gangeticus* and *Cer. buchianus*.

Though Dr. Waagen does not say so in his description of the new genus, I presume that *Xenodiscus* is really the early stage of development of *Aegoceras*, Waag., and stands in the same relation to the latter genus as does *Otoceras* and *Ophiceras*, respectively, to *Pinacoceras* and *Lytoceras*.


1
S
6
A
2b
2a
3

GEOLOGICAL SURVEY OF INDIA

Griesbach Lower Trias Cephalopoda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## EXPLANATION OF PLATES.

### PLATE I.

Figs. 1 to 3. NAUTILUS BRAHMANICUS, n. s.
Fig. 4. OTOCERAS WOODWARDI, n. s.
Fig. 5. „ var. UNDATUM, n s

### PLATE II.

Figs. 1 to 6. OTOCERAS WOODWARDI, n. s.

### PLATE III.

Figs. 1 to 7. OPHICERAS TIBETICUM, n. s.
Fig. 8 „ HIMALAYANUM, n. s.
Fig. 9 „ MEDIUM, n. s.
Fig. 10. TRACHYCERAS GIBBOSUM, n s.

### PLATE IV.

Profile of Trias and Rhætic beds of Shal-Shal in the Tibetan Himalayas. The elevation of the base of the cliff (carboniferous quartzite) is about 14,000 feet above the sea.

## ON THE ARTESIAN WELLS AT PONDICHERRY, AND THE POSSIBILITY OF FINDING SUCH SOURCES OF WATER-SUPPLY AT MADRAS, *by* WILLIAM KING, B.A., *Deputy Superintendent, Geological Survey of India.*

History and progress.

Some three years ago it was announced that operations had been commenced at Pondicherry with a view to the discovery of artesian wells,—a doubtful enough experiment when the position of that city on a wide alluvial flat bordering the sea is taken into account, and that few of the ordinary physical or stratigraphical features, usually considered as giving promise of such outflows of water, are apparent at first sight. Such features do, however, occur partially; and their possible existence became gradually so impressed on the mind of Mr. Ch. Poulain, the manager of the Savana and Oopallem cotton mills, that he urged on the proprietors the advisability of making experiments, and ultimately carried out a boring with such success that water is now issuing from the tube with a hydrostatic level of nearly three feet over the surface soil and a discharge of 44 imperial gallons in the minute.

Mr. Poulain, from time to time, during the progress of this first well, read a series of papers before the Government Commission on artesian wells, in which he gave his reasons on geological and physico-geographical grounds for expecting that water-bearing strata, or sheets of water with a head, might be tapped under the Pondicherry plain, at the same time giving short notes of the progress of his work.[1] The data so recorded and other information obtained personally from this gentleman have been largely included in the present paper.

[1] See Appendix 2.

I am also much indebted to Mr. Carriol, Chief Engineer of Pondicherry, for his guidance, and for placing of all available information and assistance at my disposal in this enquiry.

The original well at the Savana filature was commenced on the 1st February 1877, and the boring (after several accidents and a removal to a short distance) having been put down to a depth of about 174 feet, the present rising sheet of water began to flow and obtained a height of nearly a foot over the soil and a discharge of nearly 20 gallons per minute on the 10th September in the same year. The flow increased to more than double this amount, and it has now been going on steadily for more than two years.

In the succeeding year a second boring was started at the Oopallem mills, and in the remarkably short period of thirty-seven days, and at the moderate expenditure of Rs. 1,500 (not accounting for apparatus and repairs), a water-bearing stratum was tapped at about 115 feet which is now discharging 99·5 gallons a minute at a height of nearly one foot over the surface, and has continued so since the 11th October 1878.

The French Government being now convinced of the occurrence of water-sheets with a 'head,' determined on developing this unforeseen source of water-supply. A site was selected in the Jardin d'Acclimatation; and under the administration of Mr. Carriol, the Chief Engineer, a third boring was carried out with great success, a sheet of water being struck at 261 feet which has had a discharge of 146·52 gallons a minute, at 4·85 feet over the level of the soil, since the 20th March 1879. This boring was carried out with great care, details and specimens of the strata passed through having been preserved.

It is difficult to give an idea of the very charming and inspiriting effect of this fountain so opened up in these gardens, though for a so-called fountain the height of the jet is very insignificant. The large basin is raised well over the level of the gardens for the necessary distribution of the water, while a large rose is placed over the orifice of the tube, so that the water only wells up rather violently and falls in a bubbling mass about a foot over the surface of the sheet in the basin. The mere gush of clear and brilliant water in a country where one so seldom sees water in such joyous motion, rising as it does from an unknown source, makes this fountain a most fascinating and beautiful feature, and soon tends to lead one into an enthusiastic belief in the existence of similar sources, and the possibility of opening them up, in almost any moderately extensive alluvial flat on the coast or even far inland. The Savana well is ill-placed, among the mill buildings in the deep shadow of its service well or basin, and its discharge is not so great; but the Oopallem well makes a brilliant oasis of its grass-grown mound in the otherwise rather sombre factory compound.

The supply of water from this well being sufficient for the gardens, a second boring was started under the same auspices and able administration, on about the most elevated ground in Pondicherry, in the Ville Noire, with the laudable object of distributing water over the native quarter. Here the works are on the same extensive scale, and much larger piping is used. Not, however, until a depth of 550 feet has rising water been met with; and this only comes within 35 inches of the surface, with a discharge of about 20 gallons a minute. This result

is very poor, but it is hopeful, nevertheless, the other wells having also shown similar sheets with such a low hydrostatic level.

A fifth well has also been started by Mr. Cornet, one of the proprietors of the filatures, in his own compound within the city and much nearer to the sea shore. My latest information on this boring is that a stratum of rising water had been struck at 200 feet. The water is not yet very abundant, and it is only of middling quality.

Some trials have also been recently made elsewhere in this part of India, which it is just necessary to notice here. Mr. A. de Closets, C.E., of Madras, reports as follows —"A trial well I had bored in Madras at the then Napier Iron Works through strata of blue clay and sands alternately, reached at 30 yards an ascending water sheet of brackish water, above a stratum of a greenish kind of sandstone." This well was, I believe, abandoned on financial grounds. Again, in another boring now under operation in Madura, Mr. de Closets has been piercing alluvial strata with the hope of meeting a water sheet, but as yet without success.[1]

On the completion of the boring in the Jardin d'Acclimatation, the subject was brought to the notice of the Madras Government through an extract[2] from the *Moniteur Officiel* of the French Settlements in India, and an enquiry was then instituted as to the expediency of sinking such wells, and as to whether any suitable localities for artesian well-sinking were known in the Presidency. At this time I had only the data supplied in Mr. Carriol's report, and had not seen Pondicherry or its neighbourhood for nearly 22 years, so could only suggest the possibility of such wells *being found in similarly placed* alluvial flats, while *I hazarded* the speculation that the gush of the water might be due to the pressure of superincumbent alluvial strata. The interest attached to these wells is, however, so great that a personal inspection of them became necessary, and I was enabled to visit Pondicherry in December last, when the materials for this paper were collected.

## THE SAVANA BORING.

Mr. Poulain, though much interested in the strata passed through in this working and that at Oopallom, has unfortunately not given very detailed accounts of them in his papers, neither did he preserve an orderly series of specimens of the rocks. Indeed, his paramount interest and object were rather to get at the hoped-for rising sheets of water, one of which should be of a sufficient quantity and of a suitable quality for the mills which had hitherto been supplied with well-water given to depositing a coating in the boilers. The following tabular section (Table 1) has, however, been constructed from the papers he read before the Commission; it is arranged after the model of those kept at the Government borings, so as to give the details at a glance, and facilitate any correlation which may be made between the other borings.

No very detailed observations extant.

[1] In Northern India borings for water have been made to 481 feet (Calcutta), and to 701 feet (Umballa), without success. *See* Manual of the Geology of India, p. 397.

[2] See Appendix 1.

The water here is very limpid with a faint bluish-green tinge; a very slight sulphurous odour is given off. It is reported as good to the taste, savoring an apparent metallic flavour; nitrate of silver gives a faint opaline cloud, and tannin produces no change of color. No deposit is formed on the boilers at the filature. The temperature at the orifice is 33° C. or 91·4° F. Clots and fluffy masses of rusty-green vegetable matter soon gather on the surface of the water in the service well or receiving basin.

The water

The well is situated at about 1,880 yards from the seashore, and about 250 yards from the right bank of the Edoupar, a small tributary of the northern arm of the Ariankúp or Gingee river, a short distance outside and to the south-west of Pondicherry. The nearest high ground of older rocks than the alluvial deposits is the low Red Hills plateau which commences to rise from the plain at about 2 miles to the north-west.[1]

Locality.

The tube has an internal diameter of 5·57 inches, and a total length of 172·79 feet, being made up of rivetted segments of 8·20 to 9·14 feet long.

Tubing

*Table I.—The Sarana Boring.*

| No. of bed according to Mr Poulain | Arbitrary grouping of Mr King | Beds | Thickness of beds in meters | Progressive thickness in meters. | Remarks |
|---|---|---|---|---|---|
| | | Surface soil, say about | 3 00 | 3 00 | |
| 1 | A | Coarse sand, with some rounded pebbles, quartz, and sub-angular particles of (?) basalt. | 1·00 | 4 00 | 1st February 1877. |
| 2 | | Coarse sand, such as is employed in the making of lime. | 3 40 | 7·40 | |
| 3 | B | Black clay with the same sand and pebbles mixed in it. | 0 40 | 7·80 | As this clay was pierced, all the water disappeared from the tube. |
| 4 | | Black clay more compact, scarcely any sand, pearly spangles, fragments of shells. | 2·48 | 10 28 | |
| 5 | | Quartzose sand, stained with black clay, about | 0·38 | 10·66 | At 10·28, 1st rise. |
| 6 | | Pure black clay, very plastic ... | 5 34 | 16·00 | At 16·00, an accident. |
| 7 | | Black clay, containing a little sand ... | 0·58 | 16·58 | At 16·58, 2nd rise. |
| 8 | | Pure black clay, and clay mixed with fine and coarse sand. | 2·42 | 19·00 | |

[1] The height of the surface at the well over mean sea-level is 9 feet. Before the boring the water-level in the ordinary wells was 11·48 feet; but now it has risen to 8·85 feet. This increase has taken place since the surplus water of the artesian well has been allowed to flow into the tank situated in the north part of the premises.

*Table I.—The Savana Boring—contd.*

| No. of bed according to Mr. Poulain | Arbitrary grouping of Mr. King | Beds | Thickness of beds in meters | Progressive depth in meters | Remarks |
|---|---|---|---|---|---|
| 9 | C | Coarse quartzose sand brilliant and dull grains, white to yellowish red, lower down mica spangles | 8 00 | 27 00 | At 22 00, 1st gush |
| 10 | D | Black clay | 6 00 | 33 00 | At 33 2nd gush |
| 11 | E | Grey sand of extreme fineness, fluid and even viscous | 1 00 | 34 00 | Water lowers as boring proceeds |
| 12 | F | Black clay, plastic compact with some rare black and schistose pebbles | 2 00 | 36 00 | |
| 13 | G | Siliceous sand, coarse grained stained with a little clay | 1 00 | 37 00 | At 36 50 a rise |
| 14 | H | Impermeable bed of clay, less black than the previous ones containing some grains of calcareous concretions (1 to 5 millimeters cube) and others a little larger Sometimes a little sand, mixed or in thin seams | 8 00 | 45 00 | |
| 15 | | Same clay with rounded pebbles, size of peas, others a little larger, black and white | 1 00 | 46 00 | At 46 3rd gush but a fall below soil |
| 16 | | Coarse sand, with pebbles of quartz | 0 50 | 46 50 | At 46 50, water stops at 30 centimeters above soil |
| 17 | | Coarse sand, pebbles rarer mixed with fine grey fluid sand like that at 33 meters Lower in the bed pebbles still more rare, grains of sand very large (2 3 mm cube) of hyaline quartz, small debris of kaolin | 0 50 | 47 00 | |
| 18 | | Coarse sand, smaller grains and rolled pebbles | 1 00 | 48 00 | |
| 19 | I | River sand a little mixed with fine sand like sea sand, still some fragments of white clay, then the sands alternately fine and coarse (Here were noticed some particles of blackish calcined clay and some fragments resembling country brick, but Mr. Poulain hesitated at such recognition until some small sherds of pottery appeared, even then he admits that these may have fallen from above) | 2 00 | 50 00 | At 49 90, water stays at 50 centimeters, when all at once there is a 4th gush Eventually water lowers rapidly |
| 20 | | Coarse sand containing pellets of black clay as large as peas; sand fine and coarse-grained, the two sands being sometimes mixed, soiled with a little black slushy clay. | 1 00 | 51 00 | |

*Table I.—The Savana Boring*—concld.

| No. of bed according to Mr. Poulain. | Arbitrary grouping of Mr. King. | BEDS. | Thickness of beds in meters. | Progressive thickness in meters. | REMARKS. |
|---|---|---|---|---|---|
| 21 | J | Debris of friable "psammite" (? ferruginous grit) tainted with some yellow ochreous clay, mixed with sand, rolled pebbles, and some lumps of hard greyish-white limestone. | 1·68 | 52·68 | At 52·68, 5th gush, 10th September 1877. |
| 22 | | Coarse-grained blackish sand, then some debris of ferruginous grit of a deep brown colour, less friable than the preceding, mixed in the mass of coarse-grained white sand slightly soiled with yellow ochreous clay. | | | |

In this table, the strata, their separate thicknesses, the progressive depths, the remarks, &c., are collated from Mr. Poulain's papers already referred to. I have myself taken the liberty of making a tentative grouping of the strata into series of permeable and impermeable beds, or an arenaceous and argillaceous grouping, thus:—

An arbitrary grouping of the beds.

| GROUPS OF BEDS. | Feet. | Feet. |
|---|---|---|
| Surface soil | 9·84 | 9·84 |
| A.—Coarse sands | 14·43 | 24·27 |
| B.—Black clays | 38·04 | 62·31 |
| C.—Coarse sands | 26·24 | 88·55 |
| D.—Black clays | 19·68 | 108·23 |
| E.—Grey sands | 3·28 | 111·51 |
| F.—Black clays | 6·56 | 118·07 |
| G.—Sands | 3·28 | 121·35 |
| H.—Clays | 29·52 | 150·87 |
| I.—Gravelly and pebbly beds | 16·40 | 167·27 |
| J.—Sands with debris of furruginous grits | 5·51 | 172·78 |

The arenaceous beds were always loose and incoherent, never consolidated; the strata passed through are then clearly alluvial and recent. The tertiary red sandstones, or "Cuddalore sandstone" of the Survey nomenclature, cropping up in the low hills to the [illegible]-west, have not been sounded by the boring and much less the cretaceous

All alluvial strata.

strata hading up still further to the west on the shores of the great Oussandan tank west of Pondicherry.

The behaviour of the water sheets.

The permeability or otherwise of the beds is very clear in this boring: no sooner is fair clay reached and pierced than the tube (filled with water from the sand above) is gradually emptied, until sand is again reached, when water again appears.[1] A sheet of water, or a seam charged with water, was, however, struck at 54·38 feet, which rose in the tube and ran over at 3·28 feet below the surface of the soil, still above sea level and also above the level in the surrounding wells; so that here was water clearly under pressure of some kind. The seam of sand and clay being, however, very thin, the boring was pushed on through the succeeding clay, until at 62·32 feet a second sheet was found to rise 11 inches over the soil, and after a short time to 17·5 inches. However, as the boring progressed, the water fell again 3·28 feet below level of soil, and then an accident occurred to the tubing which necessitated the starting of a new boring at 2 feet to one side. In the new hole similar strata were passed through, and at 72·16 feet, water at last rose to 15·60 inches above the soil.

Above first impermeable seam.

Below the 1st seam of clays.

The curious feature in the progress of these two borings only 2 feet apart, —that in about 26 feet of coarse sand without any clay the water first rose over the soil, then gradually fell to nearly 3 feet below the surface, and finally rose again to nearly 1·5 feet over the surface,—is attributed by Mr. Poulain to faultiness in his first tube, which he thinks was not quite staunch at the rivetted joinings.[2]

In the 2nd band of clays.

A third seam of permeable material (E) was again met at 108·23 feet of about 3·5 in thickness, which gave a discharge of water at 35 inches above the soil, but the boring was continued in the hope of obtaining a better flow

At 118 feet, a 3-feet seam of sandy material only allowed of water rising to within a little more than 2 feet of the surface. It is not clear whether sufficient time was allowed here for the water to rise higher, as it ought to have done, even though retarded through a more compact condition of the sand.

Below the 2nd band of clays.

After this came 29 feet of impermeable clays (H), from below which water rose to 3 feet above the soil and then fell to 27·30 inches below that level.

The auger now passed through a more varied set of generally arenaceous beds, without any definite seams of clay or other impermeable material, yet the water rises and falls in a remarkable manner, though ultimately, at the bottom of this series, the point is reached from which the present fine flow of the Savana well rises. There are altogether some 25·35 feet of these sandy beds. After entering on this series, the water mounted slowly and stopped at 11·70 inches over the soil: afterwards it rose as high as 19·5 inches when (as graphically expresed by Mr.

[1] The fact would require that some permeable beds are quite cut off from the artesian (or any other) source, and are still unsaturated, if the word 'emptied' is to be taken literally.

[2] The explanation would suggest that the phenomenon only occurred in the first boring.

Poulain) all at once, at a stroke of the borer, the water rose rapidly and flowed out over the mouth of the tube at nearly 3·28 feet above the soil. It then fell and rose in the tube, ceased to flow, and finally lowered rapidly, at a depth of 163·57 feet. The auger still continued through what are to all appearance permeable beds, though no further rise took place until at nearly 178 feet, when there was a powerful discharge of sand. This having been gradually reduced, the water rose to a height of 11·70 inches over the soil with a discharge of 19·81 gallons a minute.

Does not imply that there are more than one sheet below last seam.

I do not think we can here, below the second band of clay, consider that more than one water sheet has been tapped. The odd behaviour of the water in its oscillations being in great measure attributable to a possible choking up of the material round the bottom of the tube as it was forced down among varied sands, in which are at times seams of clay-galls and other fragments of clayey material: while in the new movements superinduced among the water channels or passages by this suddenly opened-up vent, it is quite possible that there may have been frequent blocks. The height of the jet was, however, poor as compared with what had been attained in the earlier stages of the boring, and this and the discharge were only attained after some days. The discharge when I saw the well in December last was about 44 gallons a minute, with a hydrostatic level of about one foot over soil.

Two well defined seams or bands of clay.

For the beds exhibited by this boring: it is to be noted that there are two well-defined and thick seams of clay which act perfectly as impermeable bands, from under which water rises over the level of the soil. The lower clay seam is, however, separable into three divisions by two thin seams of sand, from each of which there was a gush of water.

## THE OOPALLEM WELL.

Position.

This is situated within the compound or yard of the Oopallem filature on the Pondicherry-Cuddalore high road, and in the depression of the same small stream passing to the south-west of Pondicherry. It is within 820 yards of the sea shore, but about 650 yards to the south of the parallel of the Savana well, and about 100 yards from the left bank of the Edoupar stream.

The tubing and discharge of water.

The present discharge is 99·5 gallons a minute at a hydrostatic level of 3·28 feet. The tube has an internal diameter of 7·08 inches, and is 119 feet long.

The water.

The water is very similar in character to that of the Savana well; if anything it appeared to me to be more sparkling and to have rather a bluer tinge. The sulphurous odour is stronger. The same vegetable matter forms and floats off on the surface, perhaps rather more quickly and in better growth owing to the free exposure to air and light; the bed of the channel leading away from the basin is coated with a somewhat similar growth, and this again is covered by a very thin brown ferruginous scum. The water was distinctly tepid to the touch in the cool weather of December, and is of about the same temperature as that of the Savana; it is drunk freely by the natives.

It is to be noted that the discharge is much over that of the Savana jet. But this appears to be in proportion with the capacities of the tubes, qualified by the different depths and the more compressed strata in the deeper boring. The discharge powers of the two tubes are as 44 to 31: the actual discharges being as 99.5 to 44.

Better discharge than in the Savana well.

The following table of the strata passed through in this boring has been sent to me by Mr. Poulain:—

*Table 2.—The Oopalem Boring.*

| No. of bed according to Mr Poulain. | Arbitrary grouping of Mr King. | BEDS | Thickness of beds in meters | Progressive thickness in meters | REMARKS |
|---|---|---|---|---|---|
| 1 | | Vegetable mould ... .. | 0.60 | 0.60 | |
| 2 | A | Fine sand with clay . ... | 2.35 | 2.95 | |
| 3 | A | Coarse sand with pebbles, and some clay near the bottom | 15.18 | 18.13 | Rising sheet to 1 meter below surface |
| 4 | A | Pebbles with sand, and some clay | 0.60 | 18.73 | |
| 5 | B | Dark clay with fine sand | 2.50 | 21.23 | |
| 6 | C | Dark and hard clay ... | 14.47 | 35.70 | Gushing water sheet. |
| 7 | D | Fine sand and pebbles | ... | ... | |

The water-level in the ordinary wells is between 6.56 and 9.67 feet below surface soil, which is 6 feet above mean sea-level.

An arbitrary grouping of the beds may be put as follows:—

| GROUPS OF BEDS | Feet | Feet |
|---|---|---|
| Surface soil . . . . . . . | 1.96 | 1.96 |
| A.—Sands and pebbly beds with clay . . . . . | 59.46 | 61.42 |
| B.—Dark clay with fine sand . . . . . . . . . | 8.20 | 69.62 |
| C.—Dark and hard clays . . . . . . . . . | 47.46 | 117.08 |

THE BORING AT THE JARDIN d' ACCLIMATATION.

The next well in order of date is that in the Jardin d' Acclimatation, situated between Savana and Oopallem, immediately on the south-west edge of the town, at about 1,450 yards from the seashore, 160 yards south of the parallel of the Savana well, and 170 yards from the left bank of the Edoupar.

Position.

The water and its discharge.

The boring was commenced on the 30th October 1878, and the present water-bearing stratum was reached on the 13th February 1879, since which time, with the exception of a few days of gradual rise, the flow has continued at the same height and rate of discharge. The water has a temperature of 34·30 C. or 93·74 F., it is very clear, with a faint bluish-green tinge, and has a slight chalybeate taste. A strong sulphurous odour is given off; and the usual vegetable scum is formed on the surface and floats away. It is drunk freely by the natives, and it boils vegetables perfectly.

Boring section.

The following tabular section (3) is compiled from one supplied to me by Mr. Carrol and from another table given in the Proceedings of the Madras Government, Revenue Department.[1] In this table also, I have attempted a grouping of the beds according to their sandy and clayey constitution:—

*Table 3.—The Boring in the Jardin d'Acclimatation.*

| No. of beds according to official table | Arbitrary grouping of Mr. King | Beds | Thickness of beds in meters | Progressive thickness in meters | Remarks |
|---|---|---|---|---|---|
| | | Surface soil | 1·33 | 1·33 | 30th Oct. 1878 |
| 1 | ... | Sand mixed with yellowish clay .. | 0·75 | 2·08 | 2·80 M., water level of surrounding wells |
| 2 | A | Clay mixed with clear grey sand | 0·35 | 2·93 | 3·60 M., mean sea-level. |
| 3 | A | Argillaceous sand, clear grey ... | 1·40 | 4·33 | |
| 4 | B | Coarse sand, bluish, containing small pebbles. | 0·30 | 4·63 | |
| 5 | B | Sand, clear grey, fine, and very fluid | 1·37 | 6·00 | |
| 6 | B | Coarse sand, bluish, small pebbles | 0·15 | 6·15 | |
| 7 | B | Coarse sand, bright grey | 0·25 | 6·40 | |
| 8 | B | Coarse sand, bluish, containing small pebbles | 0·30 | 6·70 | |
| 9 | B | Coarse sand, bluish, small pebbles, debris of 'charcoal' and decayed wood | 0·35 | 7·05 | |
| 10 | B | Coarse sand, bluish, galls of black plastic clay, and decayed wood | 0·35 | 7·40 | |
| 11 | B | Sand, very fine, bluish .. | 0·15 | 7·55 | |
| 12 | B | Coarse sand, blackish, mixed with black plastic clay. | 0·60 | 8·15 | At 10·24 M., first rise of water-level. |
| 13 | C | Black clay and fine sand ... .. | 2·59 | 10·74 | |

[1] 7th July 1879, No. 1496. *See* Appendix 1.

*Table 3.—The Boring in the Jardin d'Acclimatation*—contd.

| No. of layers | Grouping of Mr. King | Beds | Thickness of layers | Progressive depths | Remarks |
|---|---|---|---|---|---|
| 14 | D | Fine sand and blackish clay | 0 58 | 11 62 | |
| 15 | | Coarse sand with a little clay, small pebbles. | 0 40 | 12 02 | |
| 16 | E | Fine sand, decayed wood and clay | 1 58 | 13 60 | |
| 17 | | Fine pure sand | 2 20 | 15 80 | |
| 18 | F | Black compact clay, with vegetable detritus | 5 40 | 21 20 | |
| 19 | | Black clay mixed with fine and medium sand. | 2 90 | 24 10 | |
| 20 | | Black clay mixed with sand and pebbles | 0 20 | 24 30 | |
| 21 | | Black clay mixed with medium sand | 2 80 | 27 10 | |
| 22 | G | Fine sand soiled with clay | 0 20 | 27 30 | |
| 23 | | Fine grey sand | 1 10 | 28 40 | |
| 24 | | Hard black clay mixed with very fine sand | 0 15 | 28 55 | |
| 25 | | Medium sand greyish ... | 2 15 | 30 70 | |
| 26 | H | Sandy black clay | 0 15 | 30 85 | |
| 27 | | Fine grey sand | 0 55 | 31 40 | |
| 28 | | Sandy black clay | 1 20 | 32 60 | |
| 29 | | Fine sand mixed with black clay | 0 40 | 33 00 | |
| 30 | | Fine sand with clots of sandy clay .. | 0 30 | 33 30 | |
| 31 | I | Compact black clay mixed with very fine sand and some small granules of grey limestone | 6 70 | 40 00 | |
| 32 | | Plastic black clay with a few fragments of shells. | 4 00 | 44 00 | |
| 33 | | Compact black clay mixed with very fine sands | 0 75 | 44 75 | |
| 34 | | Black clay mixed with medium sand ... | 3 30 | 48 05 | |
| 35 | J | Fine sand, dull, earthy and clayey .. | 1 35 | 49 40 | |
| 36 | | Fine sand, less dull, earthy and clayey . | 5 30 | 54 70 | At 50 50 M., 1st gush. |

*Table 3.—The Boring in the Jardin d'Acclimatation*—contd.

| No. of beds according to official table | Arbitrary grouping of Mr. King. | Beds | Thickness of beds in meters. | Progressive thickness in meters. | Remarks. |
|---|---|---|---|---|---|
| 37 | K | Coarse sand, clayey, containing pebbles, morsels of conglomerate and debris of ferruginous grit. | 2 00 | 56 70 | |
| 38 | | Coarse sand, pure, containing small pebbles, conglomerates and ferruginous grit. | 2 50 | 59 20 | |
| 39 | | Coarse sand, bluish, containing small pebbles, very white clay and ferruginous grit. | 0 90 | 60 10 | |
| 40 | L | White sandy clay ... | 0 15 | 60·25 | |
| 41 | | White sand, with small pebbles, fragments of white clay and ferruginous grit. | 5·79 | 66·04 | |
| 42 | M | Greyish sand, small pebbles, friable white grit and quartzose agglomerate with iron pyrites. | 0 56 | 66 60 | |
| 43 | | Blackish sand, friable white grits, and the pyritous quartzose agglomerate | 0 80 | 67·40 | |
| 44 | | Grey sand, and the same ferruginous rock. | 0 50 | 67 90 | |
| 45 | | Greyish sand, small pebbles, the pyritous agglomerate and decayed wood. | 0 70 | 68 60 | At 68 85 M., 2nd gush. |
| 46 | | Grey sand, gravel, pyritous agglomerate, ferruginous grit. | 0 50 | 69 10 | |
| 47 | | Grey sand, gravel, small pebbles, decayed wood, fragments of white and grey clay, and the pyritous agglomerate. | 2 40 | 71 50 | |
| 48 | N | Grey sand, very fine and pure ... | 0·90 | 72·40 | |
| 49 | | Fine black-grey sand, fragments of decayed wood and vegetable detritus. | 1 20 | 73·60 | At 73·60 M., 3rd gush. |
| 50 | O | Medium sand, gravel, small pebbles, decayed wood, and pyrites. | 4·20 | 77·80 | |
| 51 | | Medium greyish sand, clots of clay, gravel, small pebbles, decayed wood, and pyrites. | 0·60 | 78·40 | At 79·34 M., 4th gush, 18th Feb. 1879. |
| 52 | | Medium grey sand, gravel, decayed wood, small pebbles, and pyrites. | 1·12 | 79·52 | |

Clayey and sandy grouping of the beds.

My tentative grouping of the beds gives the following succession:—

| | Feet | Feet |
|---|---|---|
| Superficial soil | 4·33 | 4·33 |
| A.—Clayey sands | 9·84 | 14·17 |
| B.—Alternating coarse sands | 12·52 | 26·79 |
| C.—Black clay and fine sand | 8·82 | 35·61 |
| D.—Clayey sands | 4·19 | 39·80 |
| E.—Sands without any clay | 12·39 | 52·19 |
| F.—Black clays, sometimes sandy | 37·06 | 89·25 |
| G.—Alternating sands and clays | 11·80 | 101·05 |
| H.—Alternating sandy clays and sands | 8·52 | 109·57 |
| I.—Thick beds of black clay | 48·38 | 157·95 |
| J.—Fine earthy and clayey sands | 21·81 | 179·76 |
| K.—Beds of coarse sand with some ferruginous matter | 17·71 | 197·47 |
| L.—White sands, clayey and conglomeratic | 19·48 | 216·95 |
| M.—Sands with seams of ferruginous grit | 17·90 | 234·85 |
| N.—Fine sands | 6·88 | 241·73 |
| O.—Sands, gravelly and ferruginous | 19·41 | 261·14 |

Compared with the Savana grouping.

On comparing this succession with that of the Savana well, there does not appear to be very much in common at first sight, except that if we take the same depth in each, there is then the same number of groups. This, however, goes for nothing; but on looking at the groups of beds there does appear to be some faint connexion. In the Savana section, there are four distinct seams of clay, *viz.*, B, D, F, and H, while in this section there are only F and I. B, in the first, is of about the same thickness as the upper clay in the Garden section, which is, however, at a depth of 52·19 feet. A very slight dip to the eastward, which is not an unlikely supposition, would allow of these being the same bed. The clay seam, I, in the Garden well is 48·38 feet in thickness; but its upper surface is very nearly at the same depth below F as D in the Savana well is below B. There the correlation would seem to cease, for we can hardly suppose the 19·68 feet seam (D) of the Savana to have thickened out so tremendously. No other decided clay seams are found in the Garden boring, as if F and H in the Savana might also have

run to the deep It seems more likely that D, F, and H in the Savana may have run into I in the Gardens.

Behaviour of the water sheets.

Five rising sheets of water were tapped in the Garden well. The first rise took place in C, but at a point (*vide* Table 3) which seems to indicate that the black clay and the fine sand are separate layers.

A steady rise throughout two thick bands of clays.

During the whole time the boring was going on through the groups D, E, F, G, H and I, there appears to have been a steady rise of water until the 1st gush was reached, even with the intervening (ordinarily impermeable) 37 feet of black clays of F, and the 48½ feet of thick black clays of I. It is very difficult to account for this apparent permeability of such beds, even though the boring was carried on at an average rate of more than 3 feet a day. It may have been that the partings between the separate beds of clay in each group allowed of water percolating from thinned out beds of sand: indeed if my correlation of the lower group of clay beds with the separated clay beds in the Savana section be right, then the intermediate sand beds of the latter section would thin out between the thickening clays of the F group in this boring. This closing up of the water sheets also accounts for there being no such rises of water level as those which were experienced in the Savana boring until the group H was passed.

The 1st gush takes place below the second seam of clays.

The 1st gush of water (in the Garden) took place in the group K at 185·32 feet, apparently from the freer coarse sands in the seam. On the boring being continued the water fell at last below the ground level, in the white sands of L, and so it remained until the sands of the middle of M were reached, when there was a 2nd gush, which, however, fell to 12 inches below surface in the same beds. A 3rd gush took place in the fine sands of N, but this water soon fell to level of ground. At last in the ferruginous beds of O, the 4th and permanent gush was reached.

The subsequent gushes very like those in the lower permeable seam at Savana.

Here there is little apparent correspondence between the behaviour of the springs and those of the Savana well: and certainly the intermittent action of the present water-layers is extraordinary, especially in the occurrence of the 4th gush, which, it is to be remarked, is from bed No. 52 of the Table (3), which bed does not appear to differ from 50 or 51 except in the absence of small clots of clay. It may be that these clots of clay are so matted together as to have formed a temporary impermeable layer. They are present in the bottom layers of N, from under which the 3rd gush arose, while the 1st gush came from slightly clayey beds. It seems to me that it can hardly be said that these gushes, *viz.*, the 1st, 2nd, 3rd, and 4th, are really from different water sheets; but rather that they, like the lower ones in the Savana well, are from an irregularly permeated thickness of sands and some clays which required time for free circulation to be brought about. Thus, I would suggest that both the Savana and the Garden well do after all gather their waters from the same group of sandstones.

THE BORING IN THE VILLE NOIRE

A fourth boring, in the Ville Noire, is still in operation, but as yet there is no definite information as to a satisfactory sheet of rising water having been tapped.

In progress.

The locality has been chosen on comparatively high ground, but, from the section, I fear it is altogether too near the Red Hills to give much hope of a sufficient supply of water being found in the proper alluvial deposits, though the news of a rising sheet of water is hopeful. The boring is about 800 or 900 yards from the sea, and nearly 1,250 yards north of the parallel of the Savana well; it is also about 350 yards south of a large back-water immediately north of the city.

Position.

The inner diameter of the tube is 8·4 inches, but now that a depth of 550 feet has been reached, it is proposed to insert a second tube of 6·4 inches in diameter.

Tubing.

The following sectional table (4) is translated from a copy of the books kept at the boring, and I have in it again—though there is here no such very decided grouping of the arenaceous and clayey strata as in the southern wells—attempted a classification of the beds:—

The boring section so far

*Table 4.—The Ville Noire Boring.*

| No. of bed according to official diary | Arbitrary grouping of Mr. King | BEDS | Thickness of beds in metres | Progressive thickness in metres | REMARKS |
|---|---|---|---|---|---|
| | | NATURAL EARTH | 0 50 | 0 50 | |
| 1 | ... | Fine pure sand, yellowish | 1 00 | 1 50 | |
| 2 | A | Medium sand, clean, reddish | 0 40 | 1 90 | |
| 3 | A | Fine clean sand, grey ... .. | 3 50 | 5 40 | |
| 4 | A | Fine grey earthy sand ... ... | 1·70 | 7·10 | |
| 5 | A | Fine bluish earthy sand ... ... | 3·60 | 10·70 | |
| 6 | A | Blackish sand, dirty, slimy, massive shells and crustacea, small pebbles, grey grit very hard. | 3·34 | 14 04 | Represented in bed 4 of Savana boring and perhaps by 9 and 10 in the Garden well. |
| 7 | B | Black clay, ? in laminæ, mixed with sand, shells, crustacea, small gravel, and decayed wood. | 2·27 | 16·31 | |
| 8 | B | Black plastic clay, containing decayed wood. | 4·49 | 20 80 | |
| 9 | B | Compact black clay, mixed with very fine micaceous sand, and some small calcareous granules. | 4·29 | 25·09 | |

*Table 4.—The Ville Noire Boring*—continued

| No. of bed according to official liary | Arbitrary grouping of Mr. King | Beds | Thickness of beds in metres | Progressive thickness in metres | Remarks |
|---|---|---|---|---|---|
| 10 | B | Greyish clay, mixed with very fine sand | 1 60 | 26 69 | |
| 11 | | Medium sand, soiled with black clay | 1 25 | 27 94 | |
| 12 | C | Medium sand, fine and clean grey | 0 17 | 28 11 | |
| 13 | | Coarse dirty grey sand, containing small pebbles | 4 01 | 32 12 | |
| 14 | | Black plastic clay .. | 4 45 | 36 57 | |
| 15 | | Fine black clayey sand .. | 0 40 | 36 97 | |
| 16 | D | Clay marbled with reddish and bluish tints, coarse sand and pebbles | 6 92 | 43 89 | |
| 17 | | Pale yellow medium sand, soiled with clay | 2 00 | 45 89 | |
| 18 | | Dirty grey coarse sand mixed with pebbles | 0 80 | 46 69 | |
| 19 | | Coarse sand soiled with clear yellowish clay, mixed with small pebbles of grit and ferruginous conglomerates | 1 60 | 48 29 | |
| 20 | | Coarse sand soiled with reddish clay, ferruginous pebbly grit and small pebbles | 0 80 | 49 09 | |
| 21 | E | Blueish white plastic clay, mixed with red sand and some pebbles | 1 20 | 50 29 | |
| 22 | | Pale yellow sand, gravel and pebbles | 0 40 | 50 69 | |
| 23 | | Sand soiled with reddish clay and mixed with pebbles. | 0 45 | 51 14 | |
| 24 | | Reddish yellow sand, small white and red clay galls, grit and pebbles | 9 14 | 60 28 | |
| 25 | | Yellow brown medium sand ... | 1 60 | 61·88 | |
| 26 | | Laminæ of colored clay and pebbles ... | 0 86 | 62·74 | |
| 27 | | Grey black clay with some gravel ... | 0·29 | 63 03 | |
| 28 | F | Plastic clay, ribboned black, yellow, red and grey. | 0 30 | 63 33 | |
| 29 | | Plastic black clay and a little sand ... | 0 20 | 63 53 | |
| 30 | | Coarse purple argillaceous sand, with patches of colored clay. | 1 00 | 64 53 | |

*Table 4.—The Ville Noire Boring*—continued.

| No of bed according to official diary | Arbitrary grouping of Mr King | Beds. | Thickness of beds in metres. | Progressive thicknesses in metres. | Remarks |
|---|---|---|---|---|---|
| 31 | G | Agglomeration of vegetable detritus, compact lignite and some grains of fossil resin. | 0 91 | 65 14 | |
| 32 | | Reddish clayey sand, patches of colored clay, ferruginous grit and iron pyrites. | 1 65 | 67 09 | These pyritous beds seem to be represented at about the same depths in the Garden well, down to 79·52 meters. |
| 33 | | Blood-red sand, ferruginous grit, pyritous and pebbly. | 1 05 | 68 14 | |
| 34 | | Medium sand soiled with reddish clay ... | 0·94 | 69 08 | |
| 35 | | Clear red sand and small pebbles . | 1 61 | 70 69 | |
| 36 | | Red earthy medium sand, small pebbles | 2 40 | 73 09 | |
| 37 | | Clear yellow argillaceous sand, gravel and milky-white pebbles. | 1 35 | 74 04 | |
| 38 | | Clear red sand, gravel and ferruginous grit. | 2 43 | 76 87 | |
| 39 | | Grey black argillaceous sand, small pebbles and iron pyrites. | 0 20 | 77·07 | |
| 40 | | Clear red sand, small pebbles, and patches of clay at the bottom. | 5·64 | 82 71 | |
| 41 | | Coarse grey sand, with small pebbles | 0·48 | 83·19 | |
| 42 | | Pure canary-colored sand, small white pebbles and ferruginous grit. | 1·89 | 85·08 | |
| 43 | | Golden yellow argillaceous sand and small white pebbles. | 2·81 | 87 89 | |
| 44 | | Yellowish argillaceous sand, colored sandy clay-galls and ferruginous grit. | 1·60 | 89·49 | |
| 45 | | Dirty reddish coarse sand, pebbles, ferruginous grit, and patches of colored clay. | 0·40 | 89·89 | |
| 46 | | Yellow-red sand and colored sandy clay | 2·26 | 92·15 | |
| 47 | | Fine yellow-red argillaceous sand with patches or laminæ of colored clay. | 2·37 | 94·52 | |
| 48 | | Dirty-yellow medium argillaceous sand, ferruginous grit and gravel. | 2·06 | 96·58 | |
| 49 | | Dirty-grey sand, clots of bluish sandy clay with vegetable matter. | 0·11 | 96·69 | |
| 50 | | Ashy blue plastic clay ... ... | 0·15 | 96·84 | |

*Table 4.—The Ville Noire Boring*—continued.

| No. of bed according to official diary | Arbitrary grouping of Mr. King | Beds | Thickness of beds in metres | Progressive thickness in metres | Remarks |
|---|---|---|---|---|---|
| 51 | | Grey sand with clots of colored clay . | 0·22 | 97·06 | |
| 52 | | Fine variegated argillaceous sand .. | 0·73 | 97·79 | |
| 53 | | Yellow sand with clots of variegated clay, small pebbles. | 0·33 | 98·12 | |
| 54 | G | Clear-red sand soiled with clay . | 1·75 | 99·87 | |
| 55 | | Yellowish sand and sandy clay, small pebbles. | 1·19 | 101·06 | |
| 56 | | Coarse yellow sand, soiled with clay | 2·53 | 103·59 | |
| 57 | | Ashy grey sand ... . | 0·81 | 104·40 | |
| 58 | | Ashy blue sandy clay . . | 0·49 | 104·89 | |
| 59 | H | Variegated sandy clay ... . | 0·50 | 105·39 | |
| 60 | | Grey sandy clay . . . | 3·06 | 108·45 | |
| 61 | | Fine yellowish argillaceous sand, gravel and ferruginous patches. | 6·64 | 115·09 | |
| 62 | | Clear purple argillaceous sand . | 1·00 | 116·09 | |
| 63 | | Yellow sand soiled with clay, small pebbles and ferruginous grit. | 6·89 | 122·98 | |
| 64 | | Reddish sand soiled with clay, small pebbles | 0·43 | 123·41 | |
| 65 | I | Yellowish sand soiled with clay | 1·78 | 125·19 | |
| 66 | | Reddish-grey sand soiled with clay .. | 1·57 | 126·76 | |
| 67 | | Yellow sand soiled with clay, slabs ('plaquettes') of ferruginous grit. | 5·45 | 132·21 | |
| 68 | | Fine sand, clots of black clay mixed with vegetable detritus. | 0·92 | 133·13 | |
| 69 | | Yellow sand, with slabs or patches of colored clay. | 2·98 | 136·11 | |
| 70 | | Fine bluish-white sand with slabs of iron pyrites. | 1·17 | 137·28 | |
| 71 | J | Medium grey sand ... .. | 1·80 | 139·08 | |
| 72 | | Medium grey-black sand with slabs* of iron pyrites. | 2·08 | 141·16 | * These slabs are composed of white quartz grains and iron pyrites; tolerably hard and compact. |
| 73 | | Agglomerate of vegetable detritus mixed with very fine black sand. | 0·25 | 141·41 | |

Table 4.—The Ville Noire Boring—concluded.

| No of bed according to official diary | Arbitrary grouping of Mr King. | Beds. | Thickness of beds in metres | Progressive thickness in metres | Remarks. |
|---|---|---|---|---|---|
| 74 | J | Coarse black argillaceous sand with iron pyrites. | 0 99 | 112 10 | |
| 75 | J | Ashy blue clay and vegetable matter ... | 3 13 | 115 53 | |
| 76 | J | Foliated ashy blue clay ... ... | 0 10 | 115 63 | |
| 77 | J | Medium grey-black sand ... | 1 37 | 117 00 | |
| 78 | J | Ashy blue clay, vegetable detritus, and very fine sand. | 0 10 | 147·10 | |
| 79 | J | Black sand soiled with clay, small gravel and vegetable matter. | 1·00 | 148·10 | |
| 80 | ... | Dirty black-grey sand, small pebbles ... | 1 96 | 150 06 | |
| 81 | ... | Yellow sand, ferruginous grit and conglomerates. | 0 90 | 150 96 | |
| . | | Grey sand soiled with clay, small pebbles. | 0 60 | 151 56 | |
| | | | | 161 50 | Water is rising from this depth, and flowing out at 2 96 feet below the surface level, with a discharge of 13 21 gallons a minute. |

*Tentative grouping.*

| | Feet. | Feet. |
|---|---|---|
| Natural earth | 1·64 | 1·64 |
| A.—Sands | 44·41 | 46 05 |
| B.—Thick beds of clay | 45 59 | 91 64 |
| C.—Sands, with seams of pebbles | 14 69 | 106 33 |
| D.—Clays and clayey sands | 44 18 | 150 51 |
| E.—Varied beds of sand, pebbly, conglomeratic, and clayey | 52 44 | 202 95 |
| F.—Clays and clayey sands | 8 69 | 211·64 |
| G.—Mixed beds of sand, clays, and gravels | 130 77 | 342·41 |
| H.—Sandy clays | 13·28 | 355·69 |
| I.—Sands, somewhat clayey and ferruginous | 90 72 | 446·41 |
| J.—Mixed sands, clays, and sandy or argillaceous beds, with some pyritous sands, and seams of vegetable remains | 39·32 | 485·73 |
| K.—Sands with pebbles and conglomerates | 11·34 | 497·07 |

Still in alluvial deposits.

All these beds are still essentially loose and incoherent, with the exception of the occasional bands or slabs ("plaquettes") of ferruginous grit; and so belong to the proper alluvial deposits. It is true that they are becoming ferruginous and of yellow and red colors, and are thus somewhat like beds of the Tertiary "Cuddalore sandstones" of the Red Hills plateau to the north-westward, but they are merely the debris of these sandstones, the same kind of accumulations occurring along the edge of the rise up to the Red Hills as near the village of Mootnapallem. It may then be that the auger is nearing the Tertiary beds, but I do not think it is yet in them: certainly it was not in them when I was at Pondicherry, and then the sludge pump was bringing up stuff from 500 feet deep.

Compared with the other borings.

In comparing this section with those of Savana and the gardens, it would seem as though we still had the two broad series of clays, though they are hardly so sharply defined and compact. The presence of shelly and crustacean remains in the Savana and this section is perhaps the safest ground to go on for a comparison, and these are in the upper parts of the uppermost clay bands. Such remains were not noted in the garden boring, but it may be that the clay with vegetable detritus at 69 feet answers to it. However, if these clay bands are the same, it is difficult to account for no gush or even rise in the Black Town well so far.

An attempt to explain non-rise of water.

If the seams of clayey and sandy layers, down to below the second band of clay, be the same, then some explanation may be given for the non-rise of water in this boring. From the Savana well to the Ville Noire section, there is a very slight dip to the northward of the impermeable bands, along which sufficient friction may be developed to stop a rise. Again, the Ville Noire clay seams dip to the garden well at a quicker angle: so that really, though the supposed head of water would allow of all the seams being evenly filled up with water, it may be that the flow to the dip is stronger than the tendency to rise in the Black Town well.

Doubt as to an unlimited supply of water in the Pondicherry seams.

This would open up the question, whether the discharge at the Savana and in the gardens may not be sufficient to operate against the tendency to rise in the Ville Noire; and again, whether the water-supply of these wells is so great as the implied storage from the two rivers and the wide alluvial basin in the neighbourhood of Pondicherry.

## Summary of Data and Conclusions.

The data thus obtained regarding the flow of water, the water itself, the strata passed through, and the position of the wells, and the conclusions and conjectures which I have been able to draw from them, may now be summarized as follows :—

The flow and gush of water steady.

There has been a continuous discharge from each of the wells for one year at least, and one of them has been flowing for two years and six months. The hydrostatic level gradually increased, within a short time, up to a certain point and has remained so

without any sensible diminution up to the present time. The discharge also gradually obtained its present rate, and there has been no sensible decrease.

The wells, artesian.

The gush must then be due to hydrostatic pressure, and the wells must be considered, as was always contended for by Mr. Poulain, as properly artesian.

The water the same in all the wells.

The water is generally of the same quality and constitution in each well; if anything, that of the Oopallem well is brighter, clearer, and of a bluer tinge. It contains the same vegetable germs.

The bands of permeable and impermeable strata appear to be the same in all.

The borings are all in the alluvial deposits; but one of them (that of the Ville Noire) is near the bottom of these. There is a certain relation between the beds pierced in each borehole, which leads to the conclusion that groups of them are continuous over the area tapped. The upper clay seam or band certainly appears to be the same in all; it is very nearly the same thickness throughout, and it is the estuarine set of beds usually found at such a depth on the Coromandel. The second clay seam is not so clearly represented in each section; but there are strong points of similarity. A peculiar pyritous set of beds associated with seams of vegetable debris occurs once in the garden well and twice in the boring at the Ville Noire, and that in the former appears to correspond to the upper one in the latter.

The strata have a slight dip to the eastward.

The Savana, Garden, and Oopallem wells are nearly in a line ranging, from the first, in an east-south-east line for about 470 yards to the garden, and then south-east-by-south for about 770 yards to Oopallem, that is, tolerably in the line of dip which the strata might be supposed to have in this locality.

In the Savana and Garden wells, the upper clay seam has a dip of 2° to 3° to the eastward, and from this line it rises slightly to the Ville Noire section. Very nearly at the same depth below the upper clay band comes the second seam, but it has a flatter lie; indeed, it would appear to be almost horizontal in the triangular area formed by the Savana, Garden, and Ville Noire points.

Conjecture as to the "head" of the 1st rise of water; and the Oopallem sheet.

A rise of water took place in the Gardens from the sandy beds above the upper clay seam, which seems to indicate that its head may be at no great distance from Pondicherry.

Water gushed in this and the Savana borings from the permeable band below the upper clays; but the flow did not give promise of permanency. I think, however, the Oopallem water rises from the arenaceous band between the two main clay seams.

In both the Savana and Garden wells the jet now obtained began at different levels in the arenaceous strata below the second clay seam. It is questionable whether these rise from separate sheets.

Conjectures as to the lie of the strata.

If the upper clay seam preserves its dip and is continued to the westward, it might crop up to the surface at two miles back, or in the bed of the Ariancup or Gingee river at only a few miles west of Pondicherry. It is also possible that the lower seam might crop up within six miles west of the new vents. On this it is conjecturable that the

Oopallem well may draw its waters from a source within six miles of Pondicherry.

THE PONDICHERRY-CUDDALORE ALLUVIAL BASIN.

The wells are then all in the alluvial deposits; indeed, as will be seen later on, it was not to be expected that any but very deep borings could reach the older rocks, which by their lie might be presumed to hold water with a head; it therefore becomes necessary to enquire into the condition of these deposits in this region which give this hydrostatic level to their waters at the sea-board.

Mr. Poulain's views on the source and head of water.

Mr. Poulain is, I think, firmly convinced that the head of water is gained on the distant western edge of the alluvial plain behind Pondicherry from the Pennár and Gingee rivers, his arguments being fully given in his series of papers[1] read before the Artesian Wells Commission. The facts relied on are the hydrostatic level, much diminished, however, by friction in the distance traversed by the water; the immediate growth in it, after discharge, of vegetable matter similar to that seen in the river mentioned; and an apparent rise of the hydrostatic level in accordance with an observed rise in the rivers. The endurance of the flow is again very suggestive of a constant and large supply of water, such, indeed, as we might think could only be kept up by two rivers of this size and a large basin for its reception and storage.

Remarks on these

The correspondence between the rise of the rivers and any rise in the jets requires more and very careful observation, and Mr. Poulain expressed himself to me as not being very sure on this point. The vegetable matter is certainly similar to that seen floating along the river channels, but the same growth may be observed on the surface of most wells and certainly in the channels leading from them. Little can be made out of the quality of the water, for it must have undergone many changes in its passage through the different beds, even if it percolated only along one series. I should certainly never take it to be water from the higher levels of the Gingee or Pennár, for, outside of the alluvial area these waters have travelled over gneiss which is frequently weathered, and over soda soils. To all appearance, it might have come from the great tank some 7 or 8 miles to the west of Pondicherry.

However, there is the hydrostatic level which requires a head, and some distance is required for that in a gently sloping plain. For the constant and large supply of water, so far, the difficulty is not great, the whole amount discharged from the three wells in the year being only about 160,065,975 gallons, or say 737,000 cubic yards.

The alluvial basin.

The Pondicherry-Cuddalore alluvial plain or bay may be said to have its head at the village of Allabadi on the Pennár at about 27 miles west of the sea shore. From this point, the bay widens out to the east-north-east and east-south-east, the one edge going away, without much indentation, towards Cuddalore, which town is situated on the southern seaward arm or horn of the plain, while the other bends round in two loops up

[1] Travaux des Commissions Locales, Pondicherry, 1877.

the Gingee valley before it trends round again with a south-east curve towards Pondicherry. In this way the plain widens out considerably for a time until it has a breadth of some 24 miles, and then it closes in towards the sea-coast to a breadth of some 12 miles between the low plateau headlands of the Red Hills of Pondicherry on the north and Capper Hill near Cuddalore to the south, after which it again widens out to the sea beach by the two arms or horns already mentioned, only the northern horn is flanked to the sea by the Red Hills, which drop down in low cliffs to the belt of sea sands.

Its area, &c.

The area of the plain may be roughly stated at 500 square miles, and the boundary or edge receptive of waters from the adjacent rising ground may be taken as 150 miles long. The drainage supply of this basin is, however, tremendously increased by the two large rivers flowing into it.

Surface inclinations.

An estimate of the surface inclinations may be made from a calculation by Mr. Carriol, who states that the village of Villapuram (23½ miles due west of Pondicherry) is 154·84 feet above mean sea-level, which would give a rise of 6½ feet in the mile. Allabadi at the head of the plain is about 12 miles further west, and at the same rise would be 232 feet above the sea; but as Villapuram is at the end of a spur of rather elevated ground between the two rivers, there can hardly be such a difference between it and the bed of the Pennár below the above village. It will be safer to take the level of the river bed as about the same as that of Villapuram: so that from its debouchment on the plain to the coast there is a fall of at least 4·36 feet in the mile.

Form of the basin and the lie of its alluvial deposits.

The basin in which the alluvial deposits of the plains are laid down appears to slope gradually from its western edges, but to deepen more suddenly on its north and south edges, though it again has a shelving edge on the seaward side of the Pondicherry Red Hills. The borings themselves do not show very much as to the thickness of the deposits, though that in the Ville Noire makes it 542 feet, comparatively close (about 1½ miles) to the Red Hills. As far, too, as these borings go, there appears to be a tolerably flat lie of the beds, or at any rate a very low dip of between 2° and 3° to the eastward.

The geology of the floor.

The floor of the basin is a wide hollow worn in the gneiss or bottom rock of the country, its northern and southern edges being of the overlying cretaceous and tertiary strata which were once continuous over what is now the hollow. The latter formations are dipping at low angles to the eastward, and form a slightly elevated country to the westward of Pondicherry and Cuddalore; so that a traverse from either of these places passes from the alluvium to the rising plateau hills of red tertiary sandstones and conglomerates (Cuddalore sandstones) of the Red Hills, across these and down to a lowlying belt of cretaceous rocks, and then on to the further rising grounds of the crystalline or floor rocks. At the Pondicherry side, this order of outcrop is not quite so regular; here the red sandstones have not been so completely denuded to the westward, and thus a patch (the well-known fossil wood beds) of these still remains at Trivucari lapping over the cretaceous beds on to the gneiss.

The stratigraphy of the formations older than the alluvium is thus so far favorable for artesian borings, were the latter carried to a sufficient depth; but it is just this depth and the probability of having to pass through the hard and coarse grits and conglomerates of the Cuddalore sandstones which would make them impracticable.

*Considerations on other localities suitable for artesian wells.*

The wells are then sunk in the northerly seaward corner of an extensive coastal alluvial plain or basin, into which flow two large rivers whose waters may be relied on in great measure for keeping the permeable strata well filled, and which spreads back far enough from the coast for its surface inclination to give a head to these waters. Such is the broad and patent condition of affairs here; hence in enquiring as to the suitability of other parts of the Coromandel (or even further inland) for artesian borings, the most evident requirement is that they should have all the capabilities of the Pondicherry-Cuddalore basin to ensure success.

Doubts as to the necessity for so large a basin.

Nevertheless, there are certain points (some of them already hinted at) which make me doubt whether the size of this basin or the large supply of water received into it, or even the head attainable at the entrance of the rivers on the plain, are really necessary for the discharge and hydrostatic level attained. It is a question with me whether, for instance, the same hydrostatic level could not be attained with a much lower head, at a lesser distance from the vents; there being no doubt that the supply of water, obtained so far, is not beyond what the Ariancup river could give to absorbent strata only a few miles from its mouth. The irregular oscillations of the water rise in the southern bore holes; and the failure of a rise in the Ville Noire boring through all the strata which appear to correspond to those of the former wells and for such a depth seem also to point to a head not far distant, and only a moderate supply of water. I find it hard too to believe in the implied great extension of the impervious seams or bands met within the borings; the few outcrops of alluvial strata which I have seen in high river banks having generally given indications of ultimate thinning out within comparatively short distances, for the most part up, but very often down, the river's course. It is again difficult for one to conceive that the borings, so very shallow in such a wide plain, south of the town, have run down anywhere near strata holding water absorbed in the higher reaches of the rivers within the edge of the basin.

Other localities of alluvial deposits.

The town of Cuddalore, situated as it is at the southern seaward corner of the same basin, is, on the face of it, the most obvious place to try first. But the city of Madras is for many reasons the more important site. At the same time, there would appear to be even better sites than Cuddalore, on the deltas of the Cauvery, Pennér, Kistna, and Godavari.

Madras at first sight not so favorably situated.

Madras, though on the edge of a remarkably long belt of coastal alluvium, is directly in front of only a small alluvial bay or plain, very much smaller than that of the French settlement: so that if it were necessary to go entirely on the charac-

tors of the latter area, there would not be much probability of success here Its alluvial deposits are, however, not confined to this bay, but are connected, to the north-west, with the great flat of the Cortelliar and Narnaveram river basins, the permeable beds of which may trend down in this direction.

Its proper alluvial bay small, but still possibly able to supply water with a head.

This western plain is flanked to the north and south respectively by the Red Hills and by the St. Thomas' Mount range of high ground, whence it spreads outwards and seawards, joining the Cortelliar alluvium on the one side and stretching down the coast to Covelong on the other. It extends to the westward by a long arm, at the western end of which it is again connected with the Cortelliar alluviums by a narrow neck across the south-westerly extension of the Red Hills plateau; and it sends another good arm to the south-west past the Palaveram hills. Its extreme length to the western neck is about 20 miles, the breadth between the two low headlands being about 7½ miles. The receptive edge is not more than 80 miles in length, and the area, including the stretch to the coast, is at a rough calculation about 175 square miles. It is only fed by the Triplicane (also called the Madras river and the Cooum) and the Saidapet (otherwise the Adyar) rivers, which have, however, only small drainage areas. There is a possibility, however, that a fair supply of water may be drawn in at the western neck by the narrow channel there connecting the Cortelliar alluviums with those of the Triplicane river. In fact, unless there is a supply of this kind at that point, no head of water can, I think, be reckoned on until within 8 miles of Madras, when waters would have a sufficient receptive edge and length of river bed for their collection.

There is every reason to suppose that the uppermost of the two clay bands at Pondicherry may even be found in the Madras plain, the same kind of shelly deposit having been met with in the few shallow borings which have from time to time been made, while the extent of this plain compared with the size of the streams flowing into it seems to indicate a wide-spread or westward extension of estuarine beds.

I have already expressed my opinion that the water of the Oopallem well is from the permeable band under the upper clay seam of the Pondicherry plain, and there is just a possibility that this permeable seam may crop up in the Gingee or Ariancup river a few miles west of the town. This is a bare possibility only, which, however, does not practically affect the Pondicherry supply; but it is the only supposition which gives promise of any rise from small basins like that of Madras, and it may be that the head gainable at 6 or 8 miles from the coast would be sufficient for a rise. The quantity of water is, I believe, attainable in the Madras bay, within 8 miles of the town.

The proximity of the Cortelliar and Narnaveram plains.

Fortunately, however, as I think, for Madras, it is situated on the southern arm of the Cortelliar and Narnaveram plains, and in these there are, to all appearance, all the necessary requirements as to head of water gained by distance on a gentle rise, combined with a very large reception edge. The Cortelliar plain is also joined in a remarkable way with that of the Palar river at a point above where the latter has a clear channel through the gneiss, and it is not at all improbable

that there is at this high level barrier a take-off of the Palar waters into the Cortelliar basin. There is, of course, first the chance that the permeable beds of the Cortelliar may not stretch downward to and under Madras; but this is hardly to be expected, after what is known of the tailing-up of the water-bearing strata of Pondicherry, even though that town be on the north arm of its plain, and that there is a well-known tendency of the rivers on the eastern coast to trend up to the northwards in their alluvial basins.

Obstacles in the way of an irregular bottom to be expected.

There are, on the other hand, dangers that borings may meet with obstructions or may not be able to run deep enough at Madras itself, though it is possible these may not be encountered at a short distance west or north of the city: indeed, the chances of reaching the Cortelliar beds would be increased the further north the trials were made. The line of the Palavoram and Mount ridges of gneiss may extend for some distance underneath the alluviums towards the town; in any case the mere rising ground itself has a tendency to shelve under the Adyar, and this floor would very likely come within the range of shallow borings. Again, it appears[1] that a boring was many years ago made at the then Inland Customs House at Madras, three-quarters of a mile from the sea, to the depth of 55 feet, which reached the crystalline rocks. The obstacle may indeed have been a boulder of those rocks, such being sometimes met with in the alluvium, but the likelihood is that it was a sub-alluvial extension of the Mount ridges.

The section[2] in this boring was as follows:—

| | Ft. | Ins. |
|---|---|---|
| Sand and clay | 8 | 0 |
| Light-coloured sand and clay | 1 | 0 |
| Stiff clay | 3 | 6 |
| River sand | 5 | 6 |
| Black clay mixed with sand and shales | 20 | 0 |
| Blue clay with sand and lime and pieces of ironstone | 12 | 6 |
| Granite and quartz rubble | 0 | 6 |
| Clay and gravel mixed with broken granite, quartz, mica, &c. | 9 | 0 |
| TOTAL | 55 | 0 |

[1] *See* Manual of the Geology of India, pt. I, p. 423.

[2] Newbold: Journ. Royal As. Soc, pt. VIII, p. 248.

# APPENDIX I.

No. 1426, dated 7th July 1879.

*Proceedings of the Government of Madras, Revenue Department.*

TRANSLATION.

*Extract from the "Moniteur Officiel" of the French Settlements in India, dated Friday, the 4th April 1879.*

ARTESIAN WELLS.

In publishing the report of the Colonial Engineer, President of the Commission on Artesian Wells, on the boring operations carried on in the Jardin d'Acclimatation, the Administration desires to draw attention to the important results obtained, and to the hopes which this successful experiment should give rise to as regards the interests of agriculture. It is, in effect, advisable that private industry taking advantage of the experience acquired, should apply the same processes to borings to be made in other parts of the territory.

The Administration proposes, moreover, to utilize the apparatus which the Colonial Council first thought of getting out from France, on works for which sanction will be requested from the Elective Assemblies, with the view of extending these boring operations which are more productive and useful in this Colony than anywhere else.

ENCLOSURE No. 1.

*Report on the Operations of Boring an Artesian Well in the Jardin d'Acclimatation at Pondicherry, dated Pondicherry, 24th March 1879.*

*Mons. l'Ordonnateur.*—Conformably to your communication, No. 333 of the 15th February last, I have the honor to forward a full report on the operations connected with boring an artesian well in the Jardin d'Acclimatation at Pondicherry.

In order that the report may be complete, I have deemed it necessary to go back to the formation of the Commission appointed by order of the 23rd February 1877, and to the commencement of the operations which decided the Administration to encourage and popularise an advance in the means of the Colony, and of which the results ought to prove most beneficial to agriculture and rural requirements.

Consequent on the success achieved in sinking an artesian well by the aid of the "Savana" Machine as carried out by Mr. Charles Poulain, Manager of Poulain's Spinning Factory, a Commission appointed by an order of His Excellency the Governor, dated 23rd February 1877, under the presidency of the Colonial Engineer and Chef du Service of Roads and Bridges, proposed to the Administration on the 20th of June of the same year that a complete set of machinery for boring should be procured. This Commission intimated their preference for that of Messrs. Dégoussée and Lippman to any other, and suggested that a sum of 1,200 francs should be placed at the disposal of Mr. Charles Poulain (who found himself without funds) in order that he might carry on his work.

The machinery arrived in the Colony on the 4th September 1878, and the Commission, after visiting the Jardin d'Acclimatation, were unanimously of opinion that the well ought to be sunk in the centre of the basin in that garden, that situation being the one which offered the greatest facility for irrigating so large an extent of ground presuming the probable success of the undertaking.

After fitting and erecting the crane, the works were carried on under the supervision and with the assistance of the Department of Roads and Bridges. First of all, a small well 1·80 metre deep was dug in the centre of the basin, at the bottom of which boring was begun on the 30th October 1878, commencing with tubes of a diameter of ·26 of a metre. The work which on this date has reached 79m. 52c. in depth has passed through the following series of geological strata:—

*Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry.*

| Number of Strata | Dates. | Geological Strata. | Thicknesses of Strata. | Progressive Depths. | Remarks. |
|---|---|---|---|---|---|
| | | | M. | M. | |
| 0 | 30th October 1878 | Natural earth .. .. | 1·33 | 1·33 | |
| 1 | 30th " " | Sand mixed with yellowish clay | 0·75 | 2·08 | (m. 2·80) water-level of surrounding wells. (8·60) mean sea-level. |
| 2 | 30th " " | Clay mixed with clear gray sand | 0 85 | 2·93 | |
| 3 | 31st October and 2nd Nov. 1878. | Clear gray sandy clay . | 1 40 | 4·33 | |
| 4 | 4th November 1878 | Coarse bluish sand mixed with small gravel | 0·30 | 4·63 | |
| 5 | 5th, 6th, 7th, 8th, 9th, and 11th November 1878. | Fine, clear gray sand, very fluid | 1·37 | 6·00 | |
| 6 | 12th November 1878 | Bluish gray sand mixed with small gravel | 0·15 | 6 15 | |
| 7 | 12th and 13th Nov. 1878. | Coarse clear gray sand .. | 0·25 | 6·40 | |
| 8 | 13th November 1878 | Coarse bluish sand mixed with small gravel. | 0·30 | 6·70 | |
| 9 | 13th " " | Coarse bluish sand, small gravel, fragments of charcoal and decayed wood.* | 0·35 | 7·05 | |
| 10 | 14th " " | Coarse bluish sand, lumps of plastic black clay and decayed wood. | 0·35 | 7·40 | |
| 11 | 14th " " | Very fine bluish sand ... | 0·15 | 7·55 | |
| 12 | 14th " " | Coarse blackish sand mixed with black clay. | 0·60 | 8·15 | |
| 13 | 15th " " | Black clay and fine sand ... | 2·59 | 10·74 | (10·24) first rise of water-level. |
| 14 | 15th " " | Fine sand and diluted black clay | 0·88 | 11·62 | |
| 15 | 15th, 16th Nov. 1878 | Coarse sand with a little clay and small gravel. | 0·40 | 12·02 | |

*Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry*—contd.

| Number of Strata. | Dates. | Geological Strata. | Thicknesses of Strata. | Progressive Depths. | REMARKS. |
|---|---|---|---|---|---|
| | | | M. | M. | |
| 16 | 16th, 18th „ „ | Fine sand and decayed wood ... | 1·58 | 13·60 | |
| 17 | 18th, 19th, 20th, and 21st Nov. 1878. | Fine pure sand ... ... | 2·20 | 15·80 | |
| 18 | 21st, 22nd, 23rd November 1878. | Close black clay with vegetable detritus. | 5·40 | 21·20 | |
| 19 | 23rd, 25th, and 26th November 1878. | Black clay mixed with fine and moderate sized sand. | 2·90 | 24·10 | |
| 20 | 26th November 1878 | Black clay mixed with sand and small gravel. | 0·20 | 24·30 | |
| 21 | 26th and 27th Nov. 1878. | Black clay mixed with moderate sized sand. | 2·80 | 27·10 | |
| 22 | 27th November 1878 | Fine sand stained with clay ... | 0·20 | 27·30 | |
| 23 | 27th and 28th Nov. 1878. | Fine grayish sand ... ... | 1·10 | 28·40 | |
| 24 | 28th November 1878 | Hard black clay mixed with very fine sand. | 0·15 | 28·55 | |
| 25 | 28th and 29th Nov. 1878. | Moderate sized grayish sand ... | 2·15 | 30·70 | |
| 26 | 29th November 1878 | Black sandy clay ... ... | 0·15 | 30·85 | |
| 27 | 29th „ „ | Fine gray sand ... ... | 0·55 | 31·40 | |
| 28 | 30th „ „ | Black sandy clay ... ... | 1·20 | 32·60 | |
| 29 | 30th „ „ | Fine sand mixed with clay ... | 0·40 | 33·00 | |
| 30 | 30th „ „ | Fine sand and lumps of sandy clay ... ... ... | 0·30 | 33·30 | |
| 31 | 30th November, 1st, 2nd, 3rd, 4th Dec. 1878. | Close black clay mixed with very fine sand and quantities of gray limestone. | 6·70 | 40·00 | |
| 32 | 5th, 6th, 7th, 9th, 10th, and 11th Dec. 1878. | Black plastic clay with a few fragments of shells. ... | 4·00 | 44·00 | |
| 33 | 11th December 1878 | Compact black clay mixed with fine sand. | 0·75 | 44·75 | |
| 34 | 11th, 12th, 13th Dec. 1878. | Black [illegible] mixed with moderate [illegible] | 3·30 | 48·05 | |
| 35 | 13th and 14th Dec. 1878. | Fine sand and dark earthy clay | 1·35 | 49·40 | |

*Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry*—contd.

| Number of Strata | Dates | Geological Strata | Thicknesses of Strata. | Progressive Depths | REMARKS |
|---|---|---|---|---|---|
| | | | M | M | |
| 36 | 14th, 16th, 17th, 18th Dec 1878 | Fine sand, earthy clay less dark | 5 30 | 54 70 | |
| 37 | 18th, 19th, 20th Dec 1878. | Coarse clayey sand mixed with small gravel, conglomerates and ferruginous sandstones. | 2 00 | 56 70 | (56 50) 1st gushing out of water. The interval of time between the 21st December 1878 and 2nd January 1879 was employed in clearing away the sand in order to obtain a larger discharge. |
| 38 | 20th, 21st Dec 1878, and 2nd January 1879 | Coarse pure sand (same materials as above) | 2 50 | 59 20 | |
| 39 | 3rd January 1879 | Coarse whitish sand mixed with small gravel, very white clay and ferruginous sandstones | 0 90 | 60 10 | |
| 40 | 3rd, 4th January 1879 | White sandy clay | 0 15 | 60 25 | |
| 41 | 4th, 6th, 7th, 8th January 1879 | White sand mixed with small gravel, ferruginous sandstones, fragments of white clay | 5 79 | 66 04 | |
| 42 | 9th January 1879 | Grayish sand, small gravel, white friable sandstone, quartzo metallic conglomerates and ferruginous sandstones. | 0 56 | 66 60 | |
| 43 | 10th „ „ | Blackish sand (same materials without the gravel) | 0 80 | 67 40 | |
| 44 | 10th „ „ | Coarse sand and quartzo-metallic conglomerates | 0 50 | 67 90 | |
| 45 | 11th „ „ | Grayish sand, small gravel, metallic conglomerates and decayed wood. | 0·70 | 68 60 | (68·85) 2nd gush. |
| 46 | 11th, 13th, 14th, 15th January 1879 | Gray sand, grits and metallic conglomerates | 0 50 | 69 10 | |
| 47 | 15th, 16th, 17th, 18th, 20th, 21st, 22nd, 23rd, 24th, 25th, 27th, and 28th January 1879 | Coarse sand, sand, small gravel, decayed wood, fragments of white and gray clay and metallic conglomerates. | 2 40 | 71·50 | |
| 48 | 29th, 30th, 31st January 1879. | Very fine and pure gray sand. | 0 90 | [illegible] | |
| 49 | 1st, 3rd February 1879. | Fine black and gray sand, fragments of clay, decayed wood and vegetable detritus. | [illegible] | [illegible] | ([illegible]) 3rd gush |

*Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry*—concld.

| Number of Strata | Dates. | Geological Strata. | Thicknesses of Strata | Progressive Depths | REMARKS |
|---|---|---|---|---|---|
| | | | M. | M. | |
| 50 | 3rd, 4th, 5th, 6th, and 7th February 1879. | A moderate sized sand, grits, small gravel, decayed wood and iron ore. | 4 20 | 77 80 | |
| 51 | 7th, 8th, 10th, 11th, and 12th February 1879. | Moderately gray sand lumps of clay, grits, small gravel, decayed wood and iron ore. | 0 60 | 78 40 | (79 31) 4th gush |
| 52 | 12th, 13th, 14th, and 15th February 1879. | Moderately gray sand, grits, decayed wood, small gravel and iron ore | 1 12 | 79·52 | |

Drawn up by the Colonial Engineer, Chef du Service of Roads and Bridges

A. CARRIOL,
*Pondicherry.*

*The 24th March 1879*

On the 15th November, after thirteen days of work, a rise of water-level was found at a depth of 10·74 metres. The water-level, which was originally 2·80 metres below the level of the soil, rose to 1·27 metres. The water was of the same character as that of surrounding wells, the water-level of which remained stationary at 2·80 metres.

These first 10 74 metres (which gave a mean depth sunk of ·82 of a metre per diem of ten hours of actual work) consisted of alternate layers of ordinary gravel mixed with clay, fine and very fluid sand, lumps of black plastic clay, bits of decayed wood, and of coarse blackish sand mixed with black clay, and were bored either by a rotating auger (tarière), or by means of a "soupape à boulet." This last implement produced the best results, especially in quicksand, during the whole course of operations.

From the 15th November to the 20th December, boring continued without interruption; the level of the rising water rose higher and higher; from 1·27 metres, which it had when first met with, it rose till it was not more than 95 of a metre below the surface of the ground on the 18th. It remained at this level till the 20th December, on which date at a depth of 56·50 metres, a gush of water was encountered.

This outflow showed itself on the night of the 19th. The temperature of the water was 31° centigrade, and its hydrostatic level rose ·55 of a metre above the level of the ground. During the boring, the water rose and fell intermittently, varying between ·40 and ·44 of a metre. This was the result of the continuance of the operations. On the 21st December, the hydrostatic level rose to ·99 of a metre and gave a discharge of 140 litres a minute. Work was carried on at this time in a [illegible] of coarse gravel mixed with clay and small gravel. The water-level remained stationary for some time; the discharge increased considerably, rising from 140 to 224 litres between the 21st and the 24th December. The temperature of the water was 34°) and on analysis by Mons. [illegible], 1st Class Chemist of Marine, showed

the following composition, as embodied in the Proceedings of the Commission of the 28th December 1878:—

| | | |
|---|---|---|
| Sulphate of lime | 0,1050 | Substances precipitated by soap and water. |
| Carbonate of lime, Silica, Magnesia, Iron (traces of) | 0,0210 | |
| Chloride of soda | 0,1800 | |
| TOTAL | 0,3060 | |

These proportions not constituting a perfectly drinkable water, though very useful for watering the garden, the Commission determined to carry on operations to a greater depth. The tubing was accordingly continued with pipes of the same diameter as at the beginning. From the 30th December, under the impetus given to the works, the hydrostatic level commenced to fall, and in consequence the discharge of water underwent the same diminution From 1·28 metres which it had attained, there was not more than 1·005 of a metre on the 31st December, ·83 on the 4th January 1879, and on the 6th (having attained a depth of 62·54 metres), the level was ·01 below the level of the ground.

From the 6th to the 13th January, the works were continued and pushed on to 68·75 metres. On the 13th, a second gush of water showed itself, which rose at length to 0·40 of a metre above the ground, but the piping became more and more difficult. A deviation of ·07 of a metre had already been noticed in the vertical projection of the column which caused friction at the bottom of the last pipe, the soupape à boulet continued to act, but the results were very poor. At one time, every effort that was made, could not overcome the resistance in sinking the column on account of the pressure of the sand against the sides. The situation was serious and very embarrassing. It was seen, moreover, that the hoop which protected the bottom of the first pipe was displaced, and that the "trépan" of the "soupape" struck it at every stroke and brought away fragments of it It was necessary to use repeatedly the large trépan which entirely detached the hoop and ground it into small pieces. The crane which was lifted by the pressure of the jackscrews was successively charged with weights varying from 1,920 kilos to 5,070 kilos. Notwithstanding this pressure, the resistance was still great. The "soupape à boulet" continually brought up the débris of the hoop and the pipe to which it was rivetted; the work of boring was almost at a standing, and the crane continued to rise. It was then loaded with a total weight of 19,290 kilos. A small sounding probe was lowered down the tube, which penetrated to a depth of ·55 of a metre in the ground and brought away traces of bluish clay. The boring was then at 68·81 metres, which showed the depth sunk during the day to be only ·06 of a metre. The hydrostatic level which rose for a moment to 1·03 fell to 0·95, and, on the 16th January, was not more than ·25 of a metre above the ground. It rose and fell, alternately, from ·73 to ·69 of a metre, and eventually fell down to ·12 below the ground-level, while the tubes were not able to be driven in more than ·67 of a metre in a week.

The works were proceeded with nevertheless, but the results were very poor. We were however, on the point of overcoming the resistance to the driving in of the pipe. When the column had passed the water-bearing strata, the water caused an opening between the exterior of the pipes and the ground penetrated. From that time the work became easier; resistance diminished, and the "soupape" having reached the coarse sand, operations became a great deal more satisfactory.

On the 3rd February, there was a third gush of water, the hydrostatic level of which rose to ·98 of a metre above the level of the ground. The boring had then reached to 73·60

metres. This fresh gush of water, like the one which preceded it, made the sand flow back from ·50 of a metre to 1·20 metres into the interior of the tube. The work continued by means of the small soupape à boulet, and we then attained a depth of 79·31 metres.

At length, on the 13th February, after penetrating a stratum of very fine sand mixed with grits and remains of decayed wood, the hydrostatic level which had remained at about the level of the ground rose to ·52 of a metre, and continued under the impetus given to the work to rise gradually to 1·48 metres in twenty-nine days. This is the jet we now have. The water is very clear, does not taste bad, and boils vegetables perfectly. It marks 98 on the hydrometer. Its temperature is 34°30′.

The discharge of water was, on the 13th February, at 10 A.M., 140 litres; in the evening it was 268 litres; and to-day, the 20th March, it has reached to 666 litres a minute—a quantity more than sufficient to irrigate the Jardin d'Acclimatation. After several attempts to extract the bottom of the pipe, it was discovered that the force of the rising water brought up sand to the surface, and that the detachment had been effected spontaneously. The boring has reached to 79·52 metres. It took 89 days of 10 hours each of actual work. This gave an average per diem of $\frac{79\cdot52}{89}$ = ·89 daily.

The following have been the general expenses :—

| | F. C. | F. C. |
|---|---|---|
| Construction of the crane . . . . . . | 1903·52 | 2570 55 |
| Transport and setting up, &c. . . . . . | 662·03 | |
| Value of 80m of pipes . . . . . . | 2340 00 | 3420·00 |
| Expenses of packing, freight and insurance . | 1080·00 | |
| Hire for driving in the pipes . . . . . | 1630·12 | 1630·12 |
| | TOTAL . . | 7620 67 |
| | | 2570 55 |
| | | 5050·12 |

If from this sum the cost of the crane be deducted, which was Fr. 2570·55, the real cost of the well will be only 5050·12.

This makes the cost of each running metre in boring $\frac{5050\cdot12}{79\cdot32}$ =63f. 50c.

This expenditure is really very small when we take into consideration the dreadful famine which raged through this country in 1877 and 1878 in consequence of want of water.

One can now assert with certainty after the success achieved in boring three wells within a radius of about 800 metres of each other, and at depths varying from 38·53 to 79·52 metres, that if the calamities which famines involve on the Coromandel Coast are not completely overcome, their disastrous consequences can be considerably mitigated by sinking artesian wells.

* * * * * *

This being the first attempt at boring to such a great depth in this country, I have thought that, from a scientific point of view, it would be useful to have in France a complete collection of geological specimens of the strata penetrated. With this view, I have caused a case containing an extract from the register of borings with all the specimens and four bottles of the water now issuing from the well to be deposited in the Magasin Général. I think M. l'Ordonateur that this case should be forwarded to His Excellency the Minister of Marine and Colonies, who would probably make it over either to the School of Roads and Bridges or the School of Mines.

(Signed) A. CARRIOL,
L'Ingénieur, Colonial,
Chief du Service des Points et Chausseés.

# APPENDIX II.

*Experiences of Mr. C. Poulain in the boring at the Savana Filature Extracted from "Travaux des Commissions Locales," (Commissions des Puits Artésiens). Pondicherry, 1877.*

L'outillage, dont il est inutile de donner le détail est celui employé pour le sondage à la corde appelé *sondage chinois* avec quelques modifications facilitant le travail dans les terrains que nous avons rencontrés Nous avons employé pour tuber notre trou de sonde un tuyau en cuivre rouge de 14 centimètres de diamètre intérieur et d'une épaisseur de métal de Om 003m/m. La longueur de chaque tuyau variait de 2 m. 50 c. à 3 mètres. Ils sont réunis l'un à l'autre par un manchon de même métal et de même épaisseur fixé au moyen des rivets.

Un puits de service de 2 mètres de profondeur a été creusé et un échafaudage compos de 2 bigues et 1 traverse a remplacé la chèvre qu'il aurait fallu construire.

Tout étant prêt, le sondage a commencé le 18 février; nous nous sommes servi de la cuillère à soupape de Jobard Nous étions dans cette couche de gros sable qui est très-employés dans le pays pour la fabrication du mortier. La profondeur était alors de 4 mètres, nous avions 50 centimètres de hauteur d'eau dans notre tube que nous descendions au fur et à mesure en le chargeant de gros poids de fonte et lui communiquant à force de bras un mouvement de va-et-vient au moyen d'un tourne-à-gauche formé de 2 pièces de bois à machoires boulonnées fortement sur le tuyau de tubage. Le travail marchait lentement, la quantité de sable ramenée étant très-faible. Les clapets s'engageaient souvent quoique nous ayons eu soin de garnir la charnière de ceux-ci d'un tube en caoutchouc au centre duquel passait la broche servant d'axe à ces clapets. De plus, l'écrou de retenue contre lequel il allait faire choquer le mouton à la montée pour opérer la fermeture des clapets, se détériorait. Nous fûmes obligé, plusieurs fois, d'en mâter la tête. Enfin, l'écrou se cassa, laissant remonter le mouton tandis que la cuillère à soupape restait au fond du trou. Nous n'etions alors fort heureusement qu'à 6 mètres de profondeur; ce qui permit de remener facilement la cuillère restée au fond. Nous travaillons toujours dans la même couche de sable mélé de quelques cailloux roulés, les uns blancs tels que ceux que l'on trouve au grand-étang es autres noirs, ternes et quelques-uns ayant un reflet rappelant le chatoiement de ces pierres connues sous le nom d'œil-de-chat. Nous avons également ramené de cette profondeur quelques pierres à arrêtes vives, nullement roulées, ressemblant à des débris de basalte et d'amphybole. Quelques-unes avaient une apparence verdâtre. Nous réparâmes la cuillère à soupape, mais craignant un nouvel accident, nous construisîmes une soupape à boulet qui fonctionna admirablement jusqu'à la profondeur de 7 m. 40 c. où nous rencontrâmes une couche d'argile noire mêlée de même sable et de quelques cailloux. Au bout de quelques coups de sonde, nous ramenâmes des fragments d'argile noire qui formait une couche compacte à en juger par l'effort qu'étaient obligés de faire nos hommes pour dégager l'outil. Le travail marcha encore lentement, nous étions déjà au 13 février. Nous ne ramenions à chaque coup de sonde que de fort petites quantites d'argile; nous pensâmes que notre outil géné dans sa chute par une hauteur d'eau de près de 4 mètres, n'avait pas assez de poids. Nous suspendîmes alors, au moyen d'un assemblage à boulon sur les tirants de la soupape à boulet, un cylindre en fer de 5 centimètres de diamètre et 26 centimètres de longueur. L'outil pénétra alors plus profondément dans la glaise, et en ramenait fort peu encore. Nous adaptâmes alors au couteau circulaire de la soupape à boulet le couteau en croix de l'outil de Collet de Reims, ce qui eut pour résultat de diviser cette partie du cylindre en quatre compartiments présentant chacun une surface d'adhérence bien supérieure à celle

existant précédemment Le travail marcha un peu plus rapidement et le niveau de l'eau baissant dans le tube à chaque coup de sonde, nous arrivâmes le 14 février au soir à 7 m. 80 c. La glaise devenait plus compacte et ne contenait presque pas de sable, nous y remarquâmes quelques paillettes nacrées, ayant à peine un millimètre carré de surface. Il nous vint ensuite des débris de coquilles nacrées très-molles à l'état humide se feuilletant sous l'angle. Nous restâmes dans cette couche jusqu' au 16 vers midi, l'eau avait disparu totalement du tube dans la matinée, ce qui indiquait que la couche de glaise était parfaitement imperméable La profondeur atteinte était de 10 mètres environ. Dans l'après-midi, l'eau reparut dans le tube, nous étions alors à 10 m 28 c et nous retirâmes du fond du sable quartzeux, souillé d'argile noire. Après quelques coups de sonde, l'argile noire reparaît, l'eau qui était remontée dans le tube jusqu'à 3 m. 50 c. de la surface, rebaisse et finit par disparaître; nous continuâmes notres forages en versant de l'eau dans notre tube et ramenant toujours de la glaise noire bien plastique, pure de tout melange. Nous continuâmes ainsi jusqu' au 17 au soir, nous étions arrivé à la profondeur de 16 mètres. Le tuyau de tubage descendait difficilement quoique nous ayions augmenté les poids de charge et le nombre de nos hommes agissant sur le tourne-à-gauche. Notre chef sondeur s'aperçut alors qu'il se produisait dans le tube un bruit ressemblant à la chute d'un jet d'eau dans le fond. Il était presque nuit close, nous arrêtames le travail. Le lendemain matin, le même bruit se produisait, mais le soleil était encore à l'horizon, il nous était impossible de rien distinguer dans le tube. Nous essayâmes à manœuvrer le tourne-à-gauche, la résistance était grande nous remarquâmes que le bruit de jet d'eau augmentait; nous descendîmes dans le tuyau une lampe allumée, placée dans un petit seau qui nous avait servi à prendre des échantillons d'eau dans les moments de repos.

Nous découvrîmes alors une fissure qui s'était produite à la soudure d'un des joints de nôtre tuyau. Nous décidâmes immédiatement qu'il fallait procéder au levage du tube pour en faire la réparation: après des efforts énormes au moyen de levier et de *Jack screw* le tuyau céda et vint avec facilité; mais une longueur de 11 mètres était restée dans le fond du trou de sonde et son extrémité supérieure était à 5 mètres en contrebas du sol Nous fîmes aussitôt creuser notre puits de service jusqu'au niveau de la première couche aquifère; au moyen de plongeurs, nous coulâmes 2 m. 10 c. de couronnes en terre cuite, notre tuyau se trouva ainsi dégagé de 60 centimètres du fond du nouveau puits. Pour faciliter le travail des forgerons qui devaient redresser le tuyau et y placer un système d'arrachage, nous installâmes deux pompes à incendie du modèle de la ville de Paris. Enfin, le 28, tout le mal était réparé, nous avions de plus vidé le tube de sondage qui s'était rempli jusqu'au fond et nous étions redescendu au point où l'accident nous avait surpris. Nous sommes toujours dans la même couche d'argile noire et compacte, l'eau a complètement disparu le 28 à midi et nous sommes à 16m. 58c. Vers la fin de la journée, l'eau reparaît un peu, nous espérons que c'est une couche de sable, nous donnons quelques coups de sonde, nous ramenons toujours la même argile, l'eau cependant, semble monter encore, nous en sommes inquiet, nous rappelant notre premier accident. Le tube est dur à manœuvrer; nous parvenons toutefois à le descendre de quelques centimètres en donnant un leger mouvement de va-et-vient; un dernier coup de sonde nous donne un peu de sable mélangé à l'argile. Il était presque nuit, on arrête le travail. Quel ne fût pas notre étonnement le 1er mars au matin, de trouver notre tube plein et débordant légèrement à une hauteur de 1 mètre en contre-bas du sol! L'écoulement est très-faible et n'est appréciable que lorsqu'on est près du tube nous arrêtâmes alors la descente du tube et nous fîmes sonder jusqu'au soir en travaillant au-dessous de celui-ci. L'outil même se prenait quelquefois, en remontant, au rebord inférieur du tuyau. Toute [illegible]

de l'argile mêlée de [illegible]

continue, il augmente [illegible]

st plein et déverse [illegible] est encore très-minde à un mètre au-dessous du niveau du sol.

Nous faisons vider le tuyau au moyen d'un petit seau jusqu'à la profondeur de 2 m. 50 c. au-dessous de la surface, l'eau met une demi-heure pour remonter à son niveau primitif. nous faisons descendre le tube en manœuvrant le tourne-à gauche, il descend facilement d'un mètre; l'eau coule avec un peu plus de force, l'orifice d'écoulement étant abaissé. Nous rivons un tuyau de 1 m. 20 c. et nous ajoutons un autre tuyau de 1 m. 20 c. dont le joint est fait avec de la glaise et nous arrêtons le travail après avoir donné quelques coups de sonde qui nous ramena de gros sable quartzeaux dont quelques grains sont brillants et hyalins d'autres au contraire opaques, variant du blanc au jaune-rougeâtre.

Le 3 au matin, nous constatons que l'eau a monté dans le tube et s'est arrêtée à une hauteur de 30 centimètres au-dessus du niveau du sol; nous enlevâmes le tuyau supplémentaire et nous continuâmes le travail; la sonde nous ramenait du gros sable mêlé de sable fin de couleur grisâtre; vers 10 heures du matin, l'écoulement était devenu appréciable. Nous recueillîmes le produit du déversement dans un seau jauge de 10 litres; il se remplit en 2 minutes; nous sommes à 19 mètres environ de profondeur. Le soir, le même seau a été rempli en 1' 45" sous les yeux de la Commission des puits artésiens qui avait bien voulu se transporter à l'établissement *Savana,* à la suite de sa première séance; le 4 au matin, l'eau est complètement claire et potable; quelques personnes la trouvent ferrugineuse; c'est à vérifier.

Le travail a été suspendu toute la journée du 4 qui était dimanche. L'eau a coulé toute cette journée, toute la nuit et le lendemain 5 mars, jusqu'à midi, et elle se déversait en un filet de l'épaisseur du petit doigt à 45 centimètres au-dessus du niveau du sol environnant. Nous enlevâmes le tuyau supplémentaire que nous avions placé pour vérifier le niveau hydrostatique et nous rivâmes un nouveau tuyau de 1 m. 80 c. m. de longueur. Nous reprenons la sonde et nous travaillons toujours au-dessous du niveau inférieur du tuyau, ce qui occasionne des éboulements souterrains qui maintiennent invariablement la sonde à 70 ou 80 centimètres en contre-bas de notre tuyau. Le sable qui vient, contient quelques paillettes brillantes comme précédemment. Nous descendons notre tuyau d'un mètre, ce qui met à 19 m. 58 c. m. la longueur totale du tuyau. Pendant que nous continuons à sonder, la Commission des puits artésiens vient faire sa seconde visite. Nous faisons donner quelques coups de soupape à boulet qui ramena à chaque fois le même sable. Nous procédons ensuite sous les yeux de la Commission à la vérification de la profondeur du trou de forage au moyen d'un plomb de sonde; l'opération a accusé une profondeur de 21 mètres. Nous avons remarqué que l'eau, depuis la descente du dernier mètre de tuyau, était moins abondante et par suite montait plus lentement. Le tuyau été descendu alors environ de 30 centimètres par un mouvement de va-et-vient imprimé au tourne-à-gauche. Les opérations ont été suspendues le soir et ajournées au moment où nous pourrions avoir des tuyaux pour les continuer.

Voici les remarques que nous avons faites sur la qualité de l'eau: pendant la journée du 4 mars elle est très-limpide et dégage des bulles gazeuses que nous supposons être de l'acide carbonique, n'ayant pas les moyens de le constater. Sa saveur est franchement ferrugineuse. Elle prend, par l'addition d'une solution de tannin, une teinte violet-noire, claire; elle donne un léger précipité de chlorure d'argent avec la solution d'azotate d'argent Nous en avons évaporé un litre qui a laissé un assez fort résidu. Conformément au désir de la Commission, nous avons fait remettre le 6 mars à M. le Pharmacien de 1re classe de la marine Castaing, membre de la Commission des puits artésiens, le susdit résidu en y joignant 6 litres environ de l'eau du puits de sondage et les échantillons de terre que nous avons recueillis à diverses profondeurs.

Le 6 mars, l'eau continue à couler légèrement du tuyau dont l'orifice supérieur est à 1 mètre en contre-bas du sol. L'eau ne s'est pas éclaircie encore à midi; en la filtrant au papier gris, elle devient très-limpide. Dans la soirée, elle s'éclairait complètement, l'écoule-

ment est à peu près le même que la veille. Tels sont les détails du travail auquel nous nous sommes livré jusqu'à présent dans la recherche d'une source artésienne à l'établissement *Savana*. Nous craignons le reproche d'avoir été peut-être un peu minutieux, mais nous avions à cœur d'éclairer la Commission d'une manière aussi complète qu'il était en notre pouvoir, en présence surtout de la façon gracieuse dont son président a bien voulu proposer de nous aider en nous procurant les tuyaux nécessaires pour continuer notre expérience.

Signé. C. POULAIN,
*Industriel.*

Pondichéry, le 6 mars 1877.

Nous avons continué, lorsque nous en avons eu les moyens, le fonçage du puits de *Savana* dont notre dernière note accusait une profondeur de 19 mètres 58 centimètres A 27 mètres, nous avons rencontré une couche de glaise noire (Regur) dans laquelle nous avons pénétré de 5 mètres environ; mais là, un nouvel accident nous a arrêté: notre tuyau de tubage s'est applati, puis rompu lorsque nous l'avons relevé. Cet accident était dû à plusieurs causes: l'applatissement a été produit par la poussée du sable extérieur d'une part, et par un effet de succion qui s'est produit dans le tuyau lorsqu'on retirait la soupape à boulet alors noyée dans une espèce de vase demi-fluide produite par l'argile délayée dans l'eau et qui a fait faire en quelque sorte office de piston à la dite soupape. Le mode de descente de tuyau qui avait été employé, c'est-à-dire un mouvement de va-et-vient répété a aussi sa part dans la cause du résultat fâcheux que nous subîmes. Nous ne nous décourageâmes pas et nous recommençâmes à nouveau à deux pieds plus loin le fonçage du tuyau que nous venions de retirer. Nous sommes aujourd'hui arrivé à 22 mètres et nous descendons notre tuyau au moyen d'une presse à vis qui agit sur lui dans le sens vertical. Nous avons dû aussi faire éprouver une extrême fatigue au tuyau dans l'opération du foncement parce que nous n'élargissions pas au moyen d'un alésoir notre trou de sonde avant de l'y insérer et que l'argile se dilatant au contact de l'eau l'enserrait d'une façon très-sensible. En résumé, Messieurs, ces accidents sont causés par un défaut de pratique, ayant été appelé pour la première fois de notre existence, et sans aucun guide de l'art du sondeur, à etablir un puits artésien. L'expérience acquise et un excellent ouvrage sur la question, qui a été mis à notre disposition par M. Amalric, un des propriétaires de *Savana*, nous permettront à l'avenir, nous l'espérons, d'éviter ces contre-temps. Enfin, Messieurs, nous pouvons le dire sans crainte d'être contredit, l'expérience de *Savana* a eu plusieurs résultats pour nous: 1° celui d'avoir attaché tout le monde à cette question d'intérêt général; 2° d'avoir établi le premier jalon de la nature des sols à une certaine profondeur et 3° enfin surtout, d'avoir disposé d'une façon favorable, par un commencement de preuve, les personnes haut placées qui devaient décider du sort du projet que nous avoins présenté au Conseil colonial. Nous continuons notre travail et nous en rendrons compte au fur et à mesure de son avancement avec la conviction intime que nous aurons bientôt, toutes choses égales d'ailleurs, le plaisir de vous annoncer notre complète réussite.

C. POULAIN.

Pondichéry, le 19 juin 1877.

Depuis notre dernière communication, des travaux urgents à l'établissement ne nous ont pas permis de poursuivre d'une façon continue notre sondage. Nous vous disions dans cette note que, dans notre second sondage, après l'accident arrivé au premier, nous étions parvenu à la profondeur de 22 mètres, c'est-à-dire, à la couche de sable aquifère rencontrée précédemment et qui nous donnait de l'eau à 40 centimètres au-dessus du niveau du sol. Cette fois l'eau de cette même nappe a atteint un niveau hydrostatique de 0, 50 centimètres au-dessus

du sol, soit 10 centimètres de plus que précédemment. Nous attribuons cette différence à ce que notre tuyau était plus étanche, ayant pris pour le nouveau sondage la précaution de souder à l'étain tous nos joints de tuyau rivés. Nous avons continué le fonçage dans ces sables et nous avons comme précédemment trouvé à 27 mètres de profondeur une couche de glaise que nous avons traversée. Son épaisseur est de 6 mètres environ. La sonde a rencontré ensuite, c'est-à-dire à 33 mètres de profondeur, une couche de sable gris, d'une finesse extrême, fluide et même visqueux, qui a monté rapidement d'un mètre dans le tuyau de retenue et a engagé une première fois notre soupape à boulet que nous avons retirée avec grande peine en nous servant de la traction produite par un treuil double. L'eau qui jusque-là s'était maintenue à une assez grande profondeur, monta jusqu'au niveau du sol. c'était une nouvelle nappe qui se faisait jour. Après quelques coups de sonnette, notre outil a pénétré plus profondément et une poussée subite de 1 mètre 60 de sable se produisant dans le tuyau, la soupape s'est trouvée très-fortement engagée et a résisté aux tractions les plus puissantes que nous ayons pu exercer. Nous introduisîmes alors une soupape à boulet d'un plus petit modèle, n'ayant que 0 mètre 06 cent. de diamètre et qui, pouvant fonctionner dans l'intervalle laissé libre par le câble de la grande soupape, nous permit de ramener peu à peu un volume de sable équivalent à 50 centimètres de hauteur dans le tuyau. C'est le plomb de sonde qui nous a fourni cette donnée. Nous nous aperçûmes alors que le couteau circulaire de cette petite soupape entamait notre câble au fond et en ramenait des fragments à l'état de filaments délayés dans la masse du sable. Nous construisîmes à la hâte avec un bout de tuyau une soupape à clapet de plus petite dimension encore, soit 0 mètre 04 cent. de diamètre, munie d'un couteau circulaire en bois et d'un clapet de cuir chargé d'une plaque de plomb Nous ramenâmes fort peu de sable et il contenait toujours des filaments de chanvre. Pensant que ces filaments provenaient de l'opération précédente, nous persistâmes à nous servir de ce nouvel outil. Après vingt heures de travail, les filaments venaient toujours et en grande abondance Craignant de détériorer notre câble, nous renonçâmes donc à ce moyen de dégager notre outil.

Nous fîmes alors descendre dans la colonne de retenue, à 32 mètres de profondeur le tuyau en toile, armé de sa lance, d'une de nos pompes à incendie, au moyen de laquelle nous injectâmes vivement au fond du sondage une forte quantité d'eau qui produisit un courant ascensionnel ayant assez de vitesse pour ramener de cette profondeur une grande quantité de sable fin Au bout d'une heure, nous jetâmes le plomb de sonde qui accusa une profondeur de 33 mètres 50. Nous soulevâmes alors de 30 centimètres notre tuyau de retenue en faisant agir en sens contraire notre presse à vis et le tuyau monta sans effort. En même temps un homme imprimait au câble des mouvements de torsion et de fouet, l'outil se trouva dégagé. Le câble n'a éprouvé qu'un peu d'éraillement dans une partie; les filaments provenaient principalement de l'extrémité libre de l'attache. Cet accident nous a mis aux prises avec l'un des cas les plus communs dans les terrains éboulants et fluides du genre de ceux que nous traversons. L'eau se maintient à 90 centimètres au-dessus du sol, et à ce point elle ne donne pas d'écoulement. Nous avons goûté l'eau de cette dernière nappe, elle nous a paru bonne.

Cette couche de sable n'a qu'un mètre d'épaisseur; elle ne pouvait donc nous fournir un écoulement important. Nous trouvâmes ensuite une nouvelle couche de glaise, toujours de la même nature que les précédentes c'est-à-dire noire, plastique, compacte. Quelques rares cailloux noirs et schisteux comme précédemment ont été aussi ramenés par la sonde. Le niveau de l'eau s'est abaissé dans la colonne de retenue aussitôt que celle-ci a pénétré dans la glaise. L'épaisseur de celle-ci n'est que de 2 mètres environ; il nous est venu ensuite du sable siliceux, à gros grains, souillé d'un peu de glaise; nous sommes à 36 mètres 50 de profondeur et l'eau se tient à 1 mètre en contrebas du sol au moment où nous terminons cette note.

Le dernier compte-rendu de nos essais s'arrêtait à la profondeur de 36 mètres; nous étions alors dans des sables à gros grains souillés de glaise. A 37 mètres, nous trouvâmes une argile moins noire que celles rencontrées précédemment, sèche et contenant des grains de concrétions calcaires variant de 1 à 5 millimètres cubes et d'autres un peu plus gros. Cette couche d'argile contenant parfois un peu de sable, tantôt mêlé dans la masse, tantôt par bandes minces, a continué jusqu'à 45 mètres, soit donc 8 mètres d'épaisseur pour cette couche imperméable. Notre sonde ramena ensuite de la même glaise mêlée de cailloux roulés, la plupart, de la grosseur d'un pois, les uns blancs, les autres noirs, d'autres un peu plus gros. Puis, l'argile disparut et il nous vint de gros sables avec les mêmes cailloux dont quelques-uns, de quartz bien pur et hyalin tels que ceux que l'on trouve au Grand-étang dans le *Ravin des chauves-souris* et ailleurs et que quelques personnes ont fait tailler et monter en bijoux; à cette profondeur, l'eau a atteint près d'un mètre audessus du sol et a déversé légèrement quelques minutes seulement, pendant le travail, puis est redescendue à 70 centimètres plus bas,

A 46 mètres les cailloux deviennent plus rares, le gros sable est mêlé de sable fin, gris, fluid, du genre de celui rencontré précédemment à 33 mètres. Le travail devient très-lent quoique nous nous servions d'un treuil simple pour la descente et la montée de notre outil. L'élasticité de la corde augmentant avec sa longueur (46 mètres) rend la manœuvre moins précise et plus pénible. Le tuyau descend difficilement; nous sommes souvent obligé de le soulever pour le descendre ensuite. A mesure que nous pénétrons dans cette couche, les cailloux deviennent de plus en plus rares; les grains de sable sont très-gros et presqu'entièrement composés de débris de quartz hyalin de 2 à 3 millimètres cubes de volume environ. L'eau, pendant les moments d'arrêt, monte très-lentement et s'arrête à 30 centimètres au-dessus du sol. Nous étions à la profondeur de 46m 50c lorsque la sonde nous ramena quelques petits débris d'argile blanche, en partie delayés dans l'eau; nous pûmes cependant en trouver un de la grosseur d'une noisette qui nous a permis d'en examiner les caractères qui sont les suivants: elle ne fait pas effervescence avec les acides, happe fortement à la langue et prend un poli admirable sous le frottement de l'ongle, c'est du kaolin. Les cailloux de quartz et les quelques débris d'argile indiquent que l'alluvion les a enlevés aux terrains tertiaires.

A 47 mètres, le grain du sable est moins gros que précédemment, il ne contient presque plus de cailloux roulés; à 48 mètres, le sable de rivière est un peu mêlé de sable fin ressemblant au sable de mer, il vient encore quelques fragments d'argile blanche. Puis les sables alternent, tantôt fins, tantôt gros; nous y remarquons des débris d'argile calcinée noirâtre et des fragments ressemblant à la brique du pays; nous hésitions cependant encore à croire à la presence de briques lorsque la sonde nous ramena de petits tessons de poterie commune; (nous donnons ce dernier renseignement sous toute réserve, car il peut se faire qu'ils aient été projetés du sol.) Nous étions alors à 49m 90, l'eau se tenait à 50 centimètres au-dessus du niveau du sol quand tout-à-coup, à la suite d'un coup de sonde, elle monta très-rapidement et déversa au-dessus du tube de retenue dont l'orifice était à près d'un mètre au-dessus du niveau du sol. Nous fîmes suspendre le sondage dans le but de ne pas contrarier cette nouvelle nappe qui semblait se faire jour espérant qu'elle deviendrait spontanément abondante. Nous remarquâmes, pendant l'écoulement qui dura environ 5 à 6 minutes et que nous estimons supérieur à 10 litres par minute, que l'eau avait un mouvement alternatif de montée et de descente dans le tuyau: quand l'écoulement cessa, l'eau baissa rapidement. Nous fîmes alors donner un coup de sonde qui ramena du gros sable mêlé de boulettes d'argile noire de la grosseur d'un pois, puis toujours du sable tantôt fin, tantôt à gros grains et par fois les deux sables mélangés, souillés d'un peu d'argile noire delayée.

A 51 mètres, la sonde nous ramena des débris de psammite friable et teintée par de l'argile

ocreuse, jaune et mêlés de sables, de cailloux roulés et de quelques parcelles de calcaire dur d'un blanc grisâtre. L'argile ocreuse jaune teinte les sables et l'eau qui est fortement jaunâtre. A ce moment, le travail cesse d'avancer en profondeur quoique la soupape revienne chaque fois entièrement pleine de sable. Celui-ci monte dans le tuyau dont la longueur totale est de 52m 68 et le plomb de sonde n'y accuse qu'une profondeur de 51m 75. Ces sables semblaient inépuisables, après deux jours entiers de travail, nous étions toujours au même point, enfin le troisième jour la poussée du sable s'arrêta et l'outil put descendre à la profondeur de 52m 68, L'eau monta au fur et à mesure que nous dégagions les sables et elle déversa au dessus de notre tube par tous les trous de rivet avec une certaine force, l'extrémité supérieure de notre tuyau était alors de niveau avec le sol environnant. Un petit accident arrivé à notre soupape à boulet nous obligea de suspendre pour deux heures notre travail. L'eau coula et sembla augmenter un peu et de jaunâtre qu'elle était, elle devint assez limpide. La soupape étant réparée, nous continuâmes à dégager et il nous vint deux ou trois fois du sable à gros grains noirâtres, puis des débris de grès ferrugineux (psammites) de couleur brun-foncée, moins friable que précédemment, mêlés dans la masse de sable blanc à gros grains légèrement souillé d'argile ocreuse jaune. L'eau augmenta sensiblement pendant le travail que nous arrêtâmes à 6 heures du soir, elle coula toute la nuit suivante et le matin elle se trouva d'une limpidité parfaite. Nous recueillîmes le produit de cette source dans un vase jaugé, nous trouvâmes que le débit était de 48 litres par minute. (10 Septembre 1877, 8 h. matin.)

Voici les remarques que nous faisons sur l'eau, elle est bonne au goût, sauf une saveur métallique très légère qui tend à diminuer au fur et à mesure de l'écoulement, le nitrate d'argent y produit un léger nuage opalin et le tannin n'y donne aucune coloration. La température de l'eau à l'orifice du sondage est de 33 degrés centigrades. Le point de déversement actuel est de 30 centimètres au-dessus du niveau du sol environnant.

Nous continuons à dégager le fond du trou de sonde dans l'espoir que le débit augmentera et nous avons fixé notre tuyau pour l'empêcher de descendre plus bas.

Une seconde expérience faite dans la même journée accusa un débit de 66 litres par minute. Le lendemain (11 Septembre) à 8 heures du matin, le débit est de 90 litres par minute au moment où nous terminons cette note, nous conservons l'espoir d'une nouvelle augmentation.

C. POULAIN.

Pondichéry, le 11 Septembre 1877.

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P. VANSTAVERN, ESQ.

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# RECORDS

# GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1880. [August.

THE KUMAUN LAKES, *by* W. THEOBALD, *Deputy Superintendent, Geological Survey of India.*

I cannot better preface my own notes on the Kumaun lakes, than by briefly adverting to the views regarding their origin, propounded by my colleague Mr. Ball in the Records of the Geological Survey, Vol. XI, part 2, page 174; since differing so essentially, as I do, from them, it will be more convenient to specify at the beginning wherein this divergence of opinion consists, than to break the thread of my own description by constantly-recurring allusions to Mr. Ball's paper.

I make no affectation of approaching the discussion of the vexed question of the origin of the Kumaun lakes without any bias for any particular theory, since believing, as I do, in the strongly presumptive universality of glacial conditions during the great ice age, the result of cosmical rather than local causes, it would be absurd in me to disavow any expectation of finding traces of such conditions within the Himalayan region, of all others, or to deny that such conditions may not be held to afford a plausible *primâ facie* explanation of the origin of these lakes, deserving of all our respect, till it can be demonstrated that such a presumption is erroneous. Such an error, supposing it to be one, is, or should be, very capable of disproof, and I understand Mr. Ball's paper to be such an attempted disproof, but, in my opinion, an unsuccessful one.

The Kumaun lakes have so many points of resemblance in common, both as regards elevation, physical surroundings, and geographical arrangement, that it seems not unreasonable to assume a common origin for them all, so that I shall attach less importance to the elucidation of the history of those presenting obscure features, than to the endeavour to establish satisfactorily the origin of one or more of them; and I herein differ from Mr. Ball, in that, whilst he can discern no conclusive proof of glacial action in any of those visited by him, I consider

the case fairly, not to say strongly, made out as regards some, and capable of being extended by analogy, and in default of any sufficient reason to the contrary, to all.

Mr. Ball (p. 175 *l. c.*) commences by dividing the Kumaun lakes into three classes "having certain features mutually in common," but unfortunately without specifying what these features are; an omission which must be my excuse if I fail in consequence to do justice to my colleague's views on the subject. Passing to the consideration of Naini Tál (of which a pretty lithographed sketch is given) Mr. Ball seeks to controvert the views of those who attribute a glacial origin to its basin, but quite unsuccessfully, I think. Whether this lake really lies in a true ice-cut basin or basins, is certainly not established or likely to be so by actual proof, unless the lake is ever drained, a contingency which may be dismissed from present consideration, though if Mr. Ball's section of its basin represents the general contour of its bottom, and not the contour along a single line only, there is the strongest presumption in favour of its glacial origin. I do not, however, think it necessary now to dwell at any length on Mr. Ball's speculations as to the probable nature of the bottom, but there is one remark of my colleague touching the mode in which the rock basins (supposing them to exist) have been produced, which indicates so absolute a divergence from the current ideas respecting the *modus operandi* of ice action, that I do not like to pass it without remark. Mr. Ball's words are (p. 176 *l. c.*) "supposing it to be so, the twin basins might be readily explained by the hypothesis that they had been successively excavated by the retreating end of a glacier." This is perfectly unambiguous as far as language goes, but does Mr. Ball really suppose that a glacier ever moves backwards, and if not, then what does he mean by the above words?

A glacier does its work by its weight and momentum; its movement is solely *forwards*, not necessarily downwards, but simply forwards, and away from the direction of its source. The "retreating end" of a glacier, therefore, cannot excavate in any degree, or add in its retreat, to the work it had already performed in its advance; since the word "retreat" does not involve here any sense of *retrograde motion*, but simply a contraction of the dimensions of the glacier induced by the operation of climatal causes. As the end of a jet of water *retreats* as the pressure under which the jet issues is diminished, without, however, the particles which compose the jet losing their forward motion (though its amount may be reduced), so it is with a glacier, and I am therefore at a loss to know whether, in the passage quoted, my colleague's words correctly express his meaning.[1]

I do not consider either that Mr. Ball has been particularly felicitous in his efforts to dispose of the argument adduced by Mr. H. F. Blanford for the glacial origin of the lake, from the peculiar shape of the basin, and the character of its sides, unbroken by subordinate ridges and spurs.

[1] Mr. Ball may perhaps be credited with the meaning his words would suggest to most of his readers—that the upper basin had been cut after the glacier had retreated from its position of maximum extension.—H. B. M.

Mr. Ball observes:—"It is true that there are no subordinate ridges and spurs, but such is not uncommonly found to be the case, where valleys run with the strike between hard beds, bounding softer ones, which have been eroded to form the valleys." The picture here drawn is suggestive of some great synclinal valley in Vindhyan sandstones, or in some similar group characterised by the parallelism and unbroken character of its beds, and there are doubtless many valleys which might have 'sat for the portrait,' but the entire force of the argument, as here used, depends on its applicability to the Naini basin. Of course, by introducing it in this connection, Mr. Ball implies that it is so applicable,—a view which I am wholly unable to coincide in. Mr Ball, however, having created the impression which the above sentence is calculated to convey, nowhere else lays special stress on the parallelism of the strata bounding the basin, but speaks of them as in places "much contorted and broken," and of the limestones "near the depôt" forming "irregular lenticular masses, not as beds." The fact is, the valley wherein Naini Tál nestles is surrounded by rocks, varying greatly in structure, such as splintery schists, and massive limestones, which agree in one character only, that of being very disturbed, as regards their stratigraphical arrangement, and much crushed and mechanically disintegrated as regards their petrological condition. This last condition (certainly one not unfavourable to the production of spurs by denudation) causes the hill sides to be much marked by debris (landslips perhaps Mr. Ball would say), washed down over them, but in the shallow road cuttings along the 'Mall,' the true arrangement of the strata may be seen, not as might be inferred from Mr. Ball's words, with a surface-plane and strike, coinciding with the axis of the valley, but revealing highly disturbed beds, with their ends truncated at various angles by the surface. Opinions may differ as to the value of the evidence in question, but the stratigraphical idea which Mr. Ball's words convey is certainly not that most obviously indicated on the ground.[1]

Mr. Ball also alludes to "the rigid trap axis" of the hill, but this feature I consider no less suppositious than the implied parallelism of the beds bounding the lake. I was much surprised, after what I had read of the lake, to see so little trap in its vicinity, but much of the rock in the district which might be so termed in a petrological sense, I should prefer to regard as an integral member of the schist group. Beds of this character may occur in the range in force, but to speak of them as "trap" without further comment, is, I think, likely to mislead, especially in helping to confuse their relationship with the eruptive trap, properly so called, so largely developed about Bhim Tál and Malwa Tál. Mr. Ball, moreover, does not very clearly explain in what precise way the presence of either bedded or eruptive trap confers rigidity on the range in question, and in default of a fuller exposition of Mr. Ball's views on the subject, I am unable to recognise a greater amount of "rigidity" in the hills about Naini Tál, than in any other hills in this or any other district. Did the ranges environing Naini Tál consist

[1] To most geologists Mr. Ball's words would probably suggest a valley of erosion on a broken anticlinal flexure, a condition compatible with what he claims for the case and with the facts adduced against it in the text.—H. B. M.

of soft sands and clays banked up against a "rigid trap axis," I could appreciate the dynamical appropriateness of the expression, but not so, where the ranges consist of schists and massive limestones, and the very existence of a marked or strongly differentiated axis of a more rigid character is, to say the least, a matter of the purest supposition.

Equally is Mr. Ball at variance both with Mr. H. F. Blanford and myself regarding the nature of the barrier at the outfall of Naini Tál: Mr. Blanford and myself both regarding it as a moraine, whilst Mr. Ball terms it a landslip; and I may here remark that to "landslips" (so far as I can gather) all the Kumaun lakes are, in Mr. Ball's opinion, due.

As regards the particular case of Naini Tál, it may be seriously objected to Mr. Ball's view, that the barrier is not placed where the sides of the valley are steepest, nor is the slope sufficient to suggest such a cause. A general idea of the objection here taken by me, may be gathered by referring to the sketch of the lake given in Mr. Ball's paper; but it requires a personal knowledge of the ground to realize how much bolder the slopes are at other parts, where no obstructive landslips have descended, than at the actual outfall. It may be suggested that the very descent of the "slip" has itself lowered the slope, and modified the profile of the neighbouring ground, but I do not think such is the case either here or anywhere else, and I merely allude to the notion, to prove that it has not escaped consideration. A few words will not be here out of place, touching the effects produced by a 'landslip' as contrasted with those due to a 'moraine.'

A landslip in its proper and original sense, is a somewhat rare phenomenon, (depending on certain conditions of surface, subsoil, and drainage), such as the 'undercliff' in the Isle of Wight, and such cases as quoted in White's 'Selbourne', but which are rare in the Himalayan region, though not unknown in the Salt-range. The term is, however, also applied to one of the commonest phenomena in hilly regions, the descent from a steep hill or cliff, of a mass of rocky materials, detached partly by frost perhaps in the first instance, partly by water and partly by gravity; the initial movement where the mass is considerable being possibly in some cases due to an earthquake. This being the sort of phenomenon considered by Mr. Ball as being the cause wherefrom all the Kumaun lakes have originated, it is necessary carefully to consider how far the conditions present in such cases resemble or differ from those connected with moraines, and whether they are adequate to the production of the results attributed to them. Such 'slips' as I now allude to may be broadly divided into two classes, namely, those which consist mainly of rocky fragments, detached from a steep hill side, always more or less angular and often of a large size, and 'slips' from ground where the rock is more sandy or argillaceous, and in which water is more or less the prime mover; the result being the descent, often very gradual, of a heterogenous mass of mud and stones, whose power of progression is regulated partly by the slope over which it moves, and partly by the amount of fluidity of the ingredients composing it. Slips of rock fragments of the first class are, as a rule, sufficiently obviously connected with the source whence they are derived, and [illegible]d usually at a considerable angle, the slope varying, however, with the

size and character of the materials composing it. To no such origin as this can, I think, any of the barriers of the Kumaun lakes be attributed. 'Slips' of the second class, however, far more closely simulate a 'moraine,' but those possessed of most mobility, from the greater fluidity of their composition, are in the precise ratio of such fluidity least capable of withstanding removal by rain, or of bearing upon their surface craggy masses of rock such as I should term 'erratics,' and which, if not numerous, are at all events occasional and most significant constituents of some of the barriers. Mr. Ball mentions masses of rock 10 feet in diameter, as forming part of the barrier of Naini Tál, but this is an under-estimate, as some of the masses are double and treble that size. They have certainly not fallen from any neighbouring cliff, nor are the harsh comminuted rocks in the vicinity of the lake capable of forming a stiff mud on which they could have been transported, after the fashion of a 'moraine,' and the inference I therefore draw from them is, that they are really part of a 'moraine' and not brought into their present position by any of the ordinary modes of stream action.

Of Bhim Tál, Mr. Ball's account is hardly more satisfactory, in my opinion, than in the case of Naini, with the important exception, that he himself sees a serious objection to the application to it of the 'landslip' theory. Mr. Ball's words are: "Towards the southern end of the lake on the eastern side, there is a *boulder deposit*, which extends along the bank, up to a level of perhaps 10 feet above the water." Now, this "*boulder deposit*" is, according to my interpretation, part of a lateral moraine which descended from the peak above Sangri (6,320 feet), and in conjunction with that of the main glacier to the south, helped on the diminution of glacial conditions to block the direct exit of the valley to the south, thereby creating the lake. Mr. Ball goes on to add: "The most remarkable feature about it, however, is, that it is backed by no high range on the east, so that, if derived from a landslip, the materials must have come from the west, and of necessity *temporarily* filled up a *portion* of the bed of the lake." I do not see by what stretch of ingenuity Mr. Ball can defend the above sentence from the charge of very inadequately conveying the true state of the case. The course of the lake, so far as the "boulder deposit" extends, runs north and south. As there is no high ground to the east, the material, as Mr. Ball owns, if the boulder deposit originated in any way in a landslip, must have come from the west across the lake, but in so doing must have *obliterated* it altogether. To talk of this as temporarily filling up a portion of its bed is simply trifling with the intelligence of the reader. There being no scour, how does Mr. Ball suppose such a mass of materials to have been removed, and the bed of the lake cleared of its temporary obstruction?

Mr. Ball is further forced into the admission, very remarkable in his mouth, with reference to this "*boulder deposit*," that "its appearance suggests a moraine," though this is not very consistent with the appellation he bestows on it.

In considering, too, the question of the descent of a glacier down the valley from the north-west, Mr. Ball allows himself to be influenced by a difficulty which I confess I am far too dull to perceive the force of. So far as I can understand it, the difficulty, as it presents itself to him, is the possible or probable

prolongation of a spur of rock across the valley, which, I understand Mr. Ball to argue, would be a serious, not to say insurmountable, difficulty in his mind to the idea of a glacier ever having passed along it. To me it is nothing of the sort; for I can conceive no sort or description of spur blocking or constricting a valley which could offer any bar to the passage of a glacier: for the plain and simple reason, that wherever the stream which originally excavated the valley could go, a glacier could follow, and is, moreover, not so bound by hydrostatic laws as water is in its fluid state. Further into the matter than this I confess my inability to see.

Of Naukatchia Tál and Sáth Tál Mr. Ball expresses a confident opinion that their shape and surroundings preclude the idea of glacial agency being concerned in their formation, an opinion from which I profoundly dissent, especially with reference to the former lake, which I consider one of the most remarkable lakes in Kumaun, if not in the world, as I shall endeavour soon to show.

There is one remark in Mr. Ball's "*conclusions*" (p. 181 of his paper) which I cannot pass without comment, as I am painfully compelled to own I do not realise its cogency. The remark is couched in the following words:—

"There is one point geologically which links the three larger lakes together, and that is the occurrence of trap dykes in the vicinity of each." Is it reasonable to ask us to accept this dictum for argument? Is it not rather like clothing with scientific importance the crude geographical conceptions of honest Fluellen, touching the similarity between Monmouth and Macedon, as proved by their both commencing with the letter M? Why, too, the smaller adjoining lakes should be excluded from participation in the argument supposed to accrue from the presence of the dykes in the vicinity of their larger brethren, is not obvious However, my colleague goes on to explain himself: "Now, I do not think it at all probable that the lakes are due to the original outburst of trap," an opinion in which I fully coincide, considering that such an idea is wholly beyond the bounds of the wildest possibility; but my colleague at once goes on to add: "But it seems not improbable that when the great upheaval and disturbance of the rocks of this area took place, the existence of comparatively rigid lines of trap may have been largely instrumental in determining the form which the surface assumed, and that on their flanks the soft shales, &c, may have been so much crushed and broken as to yield more easily to the subsequent operations of denudation, thus affording an abundant supply of materials for landslips, which ultimately served to close the valleys and form the lakes."

The two prominent ideas here presented are *firstly*, that "*rigid lines of trap have determined the form*" of the ground surrounding the lakes; and *secondly*, that the lakes are merely accumulations of water, dammed up by the "*abundant supply*" of soft shales washed off the flanks of the 'rigid lines of trap' in question. To this I can only say that the very existence of any such "rigid lines" is a matter of pure supposition on Mr. Ball's part, without the slightest evidence, so far as I am aware, in support thereof; and so far from the barriers which hold up the lakes

[1] The presence of an obstructing spur here has more weight against the glacial hypothesis than the absence of such spurs at Naini has in favour of it.—H. B. M.

being composed of 'soft shales,' it would be very hard to find such soft shales in any of the barriers I have examined. This is a plain issue. Are the barriers mainly composed of soft shales, or is that material mainly conspicuous in them by its absence?

Now, Mr. Ball himself tells us nothing about "soft shales" in the body of his paper. He therein describes the hills surrounding the lakes as consisting of "shales," "quartzites," "limestones," "argillaceous schists," "massive limestones," "highly indurated, but slightly calcareous mudstones," "white and purple quartzites," "greenstone," "trap," and even "granite and gneiss" (possibly) as members of the rock series of the district, but not a word of "soft shales" till we come to his 'conclusions,' wherein they are described as swathing his "rigid lines of trap," and by the "abundant supply of material" they have afforded, actually choking up the valleys, and thereby originating the lakes. In a word, Mr. Ball concludes that the Kumaun lakes have no connection whatever with former glaciers, but are due to landslips operating on soft shale, and the (to me) somewhat obscure influence of "rigid lines of trap." My own reason for regarding these lakes as glacial I shall now proceed to state.

The lakes of Kumaun may be divided into two groups,[1] *viz.*, those which lie in the direct course of an old glacier, and which may or may not occupy an ice-cut basin, and those formed by the occlusion of a valley by the projection across it of the material of a 'moraine.'

Class I embraces Bhim Tál, Malwa Tál, Naini Tál, the lowest of the Sáth Tál group, and an unnamed lake above Khurpa Tál.

Class II embraces Naukatchia Tal, Khurpa Tál, Suria Tál, and the upper lakes of the Sáth Tál group.

The origin of all is, however, identical, and putting aside all considerations of rock basins, which I have no immediate means of verifying, is due to the obstruction of local drainage, caused by the debris of old moraines on the retrocession of the glaciers at the termination of a glacial epoch.

The three principal lakes of Kumaun, Naini Tál, Bhim Tál, and Malwa Tál are situated in three separate, but parallel and adjacent drainage areas, the axis of each of which has a general south-east and north-west trend. The tract of country comprising this area is bounded on the north by so much of the hill range as extends from the vicinity of Gagan peak (7,855 feet) on the east to the Deoputhar peak (7,989 feet) on the west. Naini Tál lies a little below a horse-shoe shaped *cul de sac*, between the Deoputhar and Chini peaks, and is not only the largest (slightly) of the three, but the nearest to the culminating ridge, and whose basin may be said to display more obviously than the others the action of ice in its shape and character.

Its effluent waters give rise to the Balia river, which after a short south-easterly course, joins the Gola river a little below Ranibágh. Bhim Tál receives the drainage of the heights north of Bhuwali, from which it bears exactly south-east, while 7 miles beyond it, in the same direction is situated Naukatchia Tál

[1] For a map the reader is referred to Mr. Ball's paper (*l. c.*).

(the deepest of all the lakes according to Mr. Ball), the peculiar features of which I shall describe further on. Malwa Tál is simply an expansion of the Kalsa river, which with a south-easterly course drains the Gagan peak and adjoining heights, the drainage of all and the whole group of associated lakes being ultimately conveyed into the Gola river.

Bhim Tál and its neighbour Naukatchia Tál are separated from Malwa Tál by a lofty range with peaks from 6,413 to 6,320 in height; whilst from Naini Tál, Sáth Tál, and the lakes which drain into the Balia river, they are separated by a somewhat lower range of only 5,820 feet in height.

The most remarkable lakes are Bhim Tál and Naukatchia Tál, and their peculiar relation to each other renders it desirable to consider them together.

### BHIM TÁL & NAUKATCHIA TÁL

Even the new 1-inch maps of the country give no adequate idea of the peculiar features of the drainage of these two lakes. For example, the villages of Dhansila and Padani are situated on opposite sides of the stream which conveys away the surplus waters of Bhim Tál, a fact that it would be impossible to surmise from the map; indeed so far as I can make out, no escape whatever for the surplus waters of Bhim Tál is shown on the 1-inch map. One thing is apparent on the ground, and has been noticed by Mr. Ball, that the present drainage of Bhim Tál does not appear to be in the same direction as that it originally pursued, and I would extend the remark to Naukatchia Tál as well. Bhim Tál and Naukatchia Tál both stand in the same general south-east line, but the actual drainage line between them is slightly deflected on one side by the ridge on which Dhansila stands. At present the surplus waters of Bhim Tál make their escape about the centre of the lake on its east side, flowing under Dhansila (that is, to the north-east of it) with a prevailing south-east course as already stated. But there can be very little doubt that the original exit of the waters of the main valley, of which a submerged section now constitutes the present lake, was directly to the south and to the west of Dhansila instead of to the north-east of that village. My explanation of course is, that the escape waters found a readier passage through the lateral moraine skirting the east bank of the lake, than at the original point of discharge to the south, through and across not only the accumulated materials of the principal moraine, but the added accumulations of the eastern or lateral moraine (Mr. Ball's '*boulder*' *bed*) and a similar accession from the western slopes, which all helped to jam the throat of the gorge to the south. Be this as it may, the surplus waters now find their way beneath Dhansila, flowing to the south-east, till at a little less than halfway to Naukatchia Tál they are met by the surplus waters of that lake, flowing in an exactly opposite direction to the north-west. The hydrographical situation is peculiar, not to say embarrassing, but the result is, that the united waters of both lakes are deflected at almost a right angle to their joint courses, and flow to the south-west, through a narrow gorge in the trap ridge on which Dhansila stands, into the Gola river. Resuming our course from the above junction, in a south-eastern direction, and which would be called *down* the valley, but for the anomaly of the

stream flowing *towards* us, we at last reach Naukatchia Tál. Facing still to the south-east, we have on our left the lofty range separating the valley from Malwa Tál and on our right the low range on which Dhansila and Sirori are built. In front of us is Naukatchia Tál, and beyond Naukatchia Tál the valley comes to an abrupt end, and a very remarkable one.

As in the case of Bhim Tál, so in the present instance the original and natural course for the surplus waters of Naukatchia Tál would seem to be to the south straight into the Gola river, a distance of but a little over 6 miles, instead of which they reach the Gola by a circuitous course of 16 miles, the first 1 of which seem a reversal, as far as direction goes, of the original drainage of the valley. The main obstruction, looking across the lake in a south east direction, is a low hill, somewhat centrically situated, and which is evidently composed of rock *in situ*. On the left this hill is united with the Mahragaon range by sloping ground, much masked by detritus from the heights above, along which the road from Bhim Tál to Malwa Tál is carried. Here, too, I think, there is little doubt that the valley is closed to a higher level than the lake, by rock *in situ* On the right hand side, however, of the central hill, such does not appear to be the case, and on this side would seem to be the original and natural outlet of the lake, or of the valley prior to the conversion of part of it into a lake. The only obstacle here interposed between the waters of the lake and a precipitous valley leading straight down into the Gola river, is what I may designate as a causeway, wherein I could detect no rock *in situ*, and which resembles nothing more than a railway embankment connecting the central hill with the opposite or south-west side of the valley. This bank which might be (not that I wish to infer that it is of artificial origin) is not 50 feet broad at the top and forms the watershed between Naukatchia Tál at its immediate foot on one side and a sheer descent into the Gola river on the other; it has no appearance of a 'landslip' and any slip from the central hill would take place rather to the south-east which is its precipitous side than to the south-west where this bank connects it with the high ground opposite. The waters of the lake actually rest against this bank, without any intermediate catchment area in that quarter, and yet the lake is a deep one. If, then, this bank is not a 'landslip,' there seems no resource left but to regard it as a moraine, which crossed the valley at right angles from the heights behind Mahragaon, thereby creating the lake by obstructing the drainage. Every collateral consideration favours this view. In the first place, we must remember that there is every reason to suppose (as remarked by Mr Ball) that the original course of the stream (and in my view, of the glacier subsequently) through Bhim Tál was out and through its extreme southern end. Then the ground between Bhim Tál and Naukatchia Tál is so open and level as to suggest the possibility of its having been once continuously covered by a lake embracing in its limits both the existing lakes, and that the spot below Dhansila, where the escape waters from both lakes meet, was originally a low water-parting between them. On the supposition that the lakes were once united, this reversal of conditions is easily understood. The lakes being both simultaneously and similarly blocked at their natural outlet to the south, continued to rise and

spread, till their united waters discovered the weakest part of the barriers enclosing them. This was at Dhansila, which at once became the point of discharge for their joint waters, the constant cutting action of which has resulted in the features the ground now displays. Whilst then the glacier of Bhim Tál was descending west of Dhansila, the glaciers descending from the heights between Mahragaon (behind Naukatchia Tál) and Padani, were pushing straight across the ground immediately below them, with the result that the Padani glacier cut through the trap ridge, and initiated the channel by which the waters of both lakes *now* escape, whilst the Mahragaon[1] glacier pursued a parallel course west of Sitalahat, its 'moraines' serving to impound the drainage between Padani and Mahragaon, thereby creating Naukatchia Tál.

The point of supreme interest of course is, why a circuitous exit across a hard trap ridge should have been selected by the waters of both lakes in preference to a more direct and undeniably natural course across the apparently weaker obstacle of a landslip or 'boulder bed.' As regards a boulder bed initiating a lake, I may observe that every Himalayan gorge is full of boulders, but in no instance do they give rise to lakes. A flood may throw a bar of them across the channel, but the next flood makes a clean sweep of the obstruction. Of course the 'boulder bed' which could be presumed to have given rise to the lake could not have itself originated therein, and besides the Kumaun lakes, from their limited dimensions and sheltered situation, do not produce *boulders*, being very different from those grand Italian lakes

> "*Tu Lari maxime, tuque*
> *Fluctibus et fremitu assurgens, Benace, marino,*"

and in the deepest of them, Naukatchia Tál, the sides may be seen dipping down at a steep angle and composed of angular fragments evidently never disturbed by wave motion. The result of my own examination of the point of exit of the joint waters below Dhansila was very instructive. At Dhansila there is no doubt of the ridge whereon it stands being composed of rock *in situ*, but across the gorge through which the stream passes, that is, exactly south-east of Dhansila, I could detect no rock *in situ*. The entire ground is covered with loose subangular masses of hard trap, up to even 100 feet girth, but no rock *in situ* could I detect after a careful search. There are some rocks of course which from their composition decompose so freely at the surface, that it is not easy to find a clean natural section or exposure of them; but such is not the character of the harsh intractable trap of Malwa Tál and the neighbourhood, such as formed the bulk of all the fragments here strewed about. To me the conclusion was overwhelming, that I was on the 'moraine' of an old glacier which had wound past Dhansila, and along whose channel the escape waters of the two lakes had made their passage.

The ice work of the old glacier, sawing its way across the obstructive ridge at Dhansila, renders it easy to understand how the waters of both lakes, on their natural point of discharge being blocked, came to select this point as the

[1] That above Naukatchia Tál, not the village of the same name, north of Bhim Tál.

easiest for their new course, and such I believe to be the true explanation of an otherwise puzzling phenomenon.

The only thing to be said against it is, that it must stand or fall with the glacial hypothesis of the origin of the lakes.

## Naini Tál.

My notes on this lake need only be brief, as I have already noticed the chief points wherein I differ from Mr. Ball respecting it. The most important remark I have to make is regarding what remains of the old Naini moraine. Of course I regard the barrier as virtually composed of old moraine materials, but immediately below the 'barrier' the 'moraine' has been engulphed in the steep gorge, down which the escape waters of the lake precipitate themselves in their course to the Balia river. If, however, leaving the 'outfall' of the lake, we go along the cart-road, till we come in sight of the Brewery (*Shandh-batti* of the 1-inch map) and direct our eyes beyond it, we can see a little to the left of it (and of course below it) a small hill. This hill, in my opinion, constitutes one of the most prominent 'hummocks' of the old Naini 'moraine,' there still preserved intact, and *in situ.* The stream which below the 'outfall' of the lake has cut away and engulphed the old 'moraine' in the chasm worn by its waters, has lower down found an easier channel to the westward, and hence for some distance above and below Suria Tál, the old Naini 'moraine' still remains intact. Suria Tál is indeed merely a pool formed by the local drainage being shut up by the 'moraine' sweeping past to the south-west. The village of Gitia (which is not marked on the map, but lies west of Suria Tál) stands on the 'moraine,' and below it spreads a highly irregular, 'hummocky' surface, freckled over with monstrous angular blocks of limestone, derived from the Naini basin and constituting the actual 'body and bones' of the old 'moraine.' At least this is my idea. I confess I *did* see a difficulty once, not sufficient to outweigh the evidence afforded by the physical character of the ground, but still a difficulty, and that was, that the section displayed on the river abreast of this 'moraine' was one of ordinary river boulder gravel; very coarse no doubt, but *not* distinctly marked by the presence in it of the huge erratic masses which encumbered the surface a short distance off. I did not then know what my last season's work has placed beyond all question, that the 'moraines,' to whose action I attribute the formation of the Kumaun lakes, are far newer than the old gravels filling the valleys, and on which old gravels they may occasionally be seen to rest. I shall not here enter further on this important discovery, beyond saying that it at once disposes of the difficulty I once felt in the fact of the huge 'erratics' embedded in the 'moraines' (as I regard them) not being seen in the old gravels; but the full discussion of this question must be reserved for another paper.

## Malwa Tál.

This lake, if the form of its basin is less suggestive of a glacier than is the case with either Naini Tál or Bhim Tál, is one which it is, on the other hand, more difficult to regard as due to a landslip than almost any lake in Kumaun.

It lies in the direct course of what in the rains must be a considerable river, and though the sides of the valley are steep, they do not so materially differ in this or any other respect from other gorges in the hills as to afford an adequate explanation why a 'slip' from them of loose materials should produce a result which we cannot trace elsewhere where similar physical features prevail. I have already dwelt on the point that banks of shingle (and fallen detritus from the sides of the valley would share the same fate) do not in Himalayan streams, be they large or small, give rise to permanent lakes, and it is therefore difficult to understand how Malwa Tál comes to occupy the position it does, save on the supposition that it lies in a basin cut out of the rock by a glacier. On the descent to Malwa Tál by the road from Bhim Tál some very hard and massive trap is seen, and it appears as though a band of this rock crosses the valley just below the lake. If this supposition is correct, and if a glacier ever did descend the valley, the natural result would be the formation of a rock basin in the position now occupied by the lake, owing to the more energetic excavation effected by the glacier in the comparatively softer rocks above than on the hard band of rocks which may be considered as forming the lake sill at its point of discharge. It is true Mr. Ball declares no rock *in situ* is there visible, but without admitting that this fact has been satisfactorily established, or can be by a mere superficial examination, I would suggest that, considering the steepness of the sides of the valley, we may not unnaturally expect to find the bottom covered with a considerable amount of loose debris, quite sufficient to conceal any exposure of rock at the surface.

From different aspects, therefore, do the three chief lakes of Kumaun—Malwa Tál on the one hand and Naini Tál and Bhim Tál on the other—give strong countenance to the idea that they one and all originate from glacial agency.

### KHURPA TÁL.

This lake, which every traveller to Naini Tál from Káladungi must have remarked after turning the corner of the spur which descends from Deoputhar peak, is a little cocked-hat sort of depression, immediately below the road, encircled by rather steep sides, and with no visible outlet. Its natural outlet should be at its northern end, and percolation through a barrier of loose stony materials in that quarter no doubt suffices to carry off its surplus waters. But what is the nature of this barrier? The choice avowedly lies between Mr. Ball's theory of lake formation in these hills by "landslips" and mine by "moraines." It is to be regretted that Mr. Ball does not seem to have examined this lake, since it is one which, in my opinion, places the "landslip" theory entirely 'out of court.' In the case of Khurpa Tál the only direction whence the materials of the barrier almost encircling it could have been derived by a slip is from the abrupt flanks of the Deoputhar spur to the north-west. But the lake itself nestles at the foot of the spur and occupies the position of the hypotenuse of the slope which such a fall of materials would have created, and I need hardly point out, that no forces of nature could create a lake in such a position, that is on the slope or hypotenuse of a mass of fallen rock. Regarding the 'barrier,' however, as a 'moraine,' no difficulty is

encountered. The glacier which brought down the 'moraine' in question, descended in a southerly direction from the peak of 7,989 feet, standing at the head of the Naini basin, and from the opposite side from that whence the Naini glacier itself descended The valley traversed by this glacier (and along which the road to Naini from Káladungi winds) is towards its head blocked, or encumbered with a confused mass of angular blocks, which in part at least represents the old 'moraine,' though the Deoputhar ridge and the Iarputhar ridge on the opposite side are both so steep that avalanches and landslips may have largely added to its original mass. The progressive movement, however, of the bulk of this mass can, I think, only have been effected by ice, as the blocks composing it are so large and angular, the slope so high, and the surface so incapable of generating a large stream, from the water sinking engulphed in the interstices between the blocks, that fluviatile action is impossible Some halfway down the valley, this mass, which I designate a moraine, terminates in a steep bluff, precisely resembling, on a large scale an unfinished railway embankment, and below this lies the unnamed lake (or lakes, for the map shows two), across the outlet sluice of which the road is carried towards Naini after passing Khurpa Tál. Below this outlet sluice the valley rapidly falls (the moraine being here probably engulphed in precisely the same fashion as is the case below the Naini outfall), till past the old iron furnace, which stands nearly in its path, when the usual and characteristic components of a moraine are met with in profusion all round the spot on which the large bungalow, beyond the furnace, is built, and it is this moraine which intercepts a small portion of the drainage from the Deoputhar spur, and thereby gives rise to the little cocked-hat, dignified by the name of Khurpa Tál, but the interest and value of which as bearing on the origin of the Kumaun lakes is in inverse ratio to its tiny dimensions. There is one point, perhaps, which calls for notice in connection with the above small unnamed lakes, and that is, that they lie directly in the path as it were of the above 'moraine' (as I regard it, which I have described as terminating in a steep bluff) and occupy an intermediate space, comparatively free from large blocks between the moraine above them, and the similar heterogenous assemblage of rocky materials, met with lower down around Khurpa Tál. The reason is, in my opinion, not far to seek if we reflect on the conditions under which such a 'moraine' was formed in so rocky and precipitous a gorge as that east of the Deoputhar ridge. A 'moraine' is made up in varying proportions, according to the character of the rocks, of materials projected on to it in a more or less irregular fashion from both sides of the gorge or valley down which it is slowly progressing, and comparatively bald places may be left on it, wherein few or no large blocks may be found. The same aspect of the surface may also be induced by the filling up of irregular dips therein by ordinary rainwash, the silting up of all interstices between the larger blocks being the probable cause of the small unnamed lake, in question

## SÁTH TÁL.

The group of Sáth Tál, or seven lakes, as the name implies, is represented on the map by but three—namely, a small one to the north, a large one to the south,

evidently compounded of two or more contiguous basins united, and a minute lake to the west. As in the case of Bhim Tál and Naukatchia Tál the drainage of these lakes can only be indistinctly made out from the map. The small lake to the west is the lowest, and the drainage from the other lakes is passed through it. It is mainly remarkable, as affording a complete disproof of the notion of any overpowering rush of water, being the agent whereby the large blocks seen in the barrier of the large lake just above it were brought down to their present position, as any such rush of water so laden with stones and mud must have simply obliterated this little hollow, as easily as a man's thumb wipes out a spot of ink. The barrier below it is of large rough stones, fallen mainly from the hills adjoining it, which are so permeable that they do not allow its waters to ever stand for long at a high level; but although thus permeable to clear, or moderately turbid water, anything like a moving flood of mud capable of bringing down enormous masses of rock, must have filled up the lake flush with its barrier, and then passed onwards down the gorge. But this obliteration of the tiny basin has not occurred, therefore no such floods can have ever passed over it.

The uppermost lake to the north is a little cocked-hat of a lake with steep sides of loose materials, and without visible outlet, in this respect resembling Khurpa Tál. Its surplus waters, however, find an exit by percolation through the barrier (moraine) separating it from the larger lake, whose surplus waters they join below the barrier. The larger lake is created by the obstruction caused by the above barrier. This barrier is a huge bank of earth and stones, some of the embedded blocks of rocks measuring 30 or 40 feet in girth. This mass of materials, which I cannot but regard as a 'moraine,' has crept down from almost due north, till arrested by the hill whereon Siloti stands. The impounded drainage from the eastward has consequently gathered into the form of a lake of very irregular shape, the escape waters from which have scoured a passage for themselves, between the termination of the moraine and the mountain side, whereon it abuts, and whereby it became arrested and deflected to the west from its north and south course. It is an objection in the mind of some, who are opposed to the idea of ice action, that the ultimate source or head of this moraine is not quite a mile off. This, so far from being a valid obstacle to the view adopted by me, is probably, as I shall endeavour soon to show, the main cause of the very existence now of the lake, and moreover such objectors should reflect that if a limited catchment area is opposed to the genesis of a large moraine, *a fortiori* is it incapable of giving birth to a stream adequate to transporting such blocks as help to form the barrier in question.

### CONCLUDING REMARKS.

Having attempted in the previous pages to establish a case in favour of the idea that glaciers have been the proximate agents in the formation of the lakes of Kumaun, if not by the actual excavation of a rock basin in all cases, at least by the obstruction, caused on their retrocession, by the large accumulations of 'moraine' matter abandoned in their wake, I would offer a few words touching some objections which may be urged against my views.

It will not be contended, I think, and certainly not by myself, that the Kumaun district is distinguished *cæteris paribus*, as regards climate or as regards any occult orographical features, from any similar and corresponding area of the Himalayan region in general. If, then, the Kumaun lakes are due to glaciers, and if (as I hold) similar glacial conditions extended far and wide beyond the limits of Kumaun, how comes it, it may not impertinently be asked, that the entire Himalayan region is not similarly dotted over with lakes, large and small, as in a part of Kumaun? How comes a cause, exercised over so wide an area, to be attested by results confined within such narrow limits? For my part I frankly accept the first deduction, and believe that the entire Himalayan region was once dotted over with lakes, originating in the same causes and in the same manner as those of Kumaun, but from the physical or petrological character of the rocks in the vicinage of the Kumaun lakes they have remained (or many of them), whilst the great majority of the lakes of contemporary origin over the entire Himalayan region have disappeared under the operation of ordinary denudational forces. Malwa Tál illustrates, in my opinion, the process in question. It is one of the largest lakes in Kumaun, and possesses out of all comparison the largest catchment. Under any circumstances of origin, we might therefore expect a barrier of corresponding dimensions. But 'barrier' there is none save the artificial sluice wall. True, one may potter about the outfall without detecting rock *in situ*, but there is nothing analogous to the mole-like mass which constitutes the 'barriers' of the other lakes. Doubtless the reason is, the flood waters of its large catchment area have swept the whole away, and the lake owes its continued existence to the fact of its having been endowed with not only a barrier, but a true rock basin likewise. The one has disappeared, the other remains. * This, it may be alleged, is mere supposition, but it is not unwarranted, I think, by the circumstances, for other *raison d' être* for this lake save a rock basin, I can imagine none.

The hard limestones, traps, and trap-like schists, of this part of Kumaun readily break up into a confused heap of fragments of all sizes, and the fragments heaped together (as I argue in the shape of moraines) form an obstacle, practically, in most cases, unassailable by the slender supply of water passed over them. In such a case as Malwa Tál with its large catchment area, the 'barrier' does go. In Naini Tál and perhaps other instances, the said 'barrier' becomes attacked in places, and undercut and partially engulphed in the chasm formed by the stream, which is wholly powerless to remove it in any more direct fashion, whilst in the smaller lakes, with no catchment area to speak of, beyond their sloping sides, we see the pent up waters finding their way out by percolation, through the loose materials which surround them.

I doubt not moreover that an additional argument and illustration of the view here set forth will be found when the lakes high up on the frontier of Northern Hazára come to be examined. These, too, clearly have very small catchment areas, to which, as in Kumaun, their survival is probably due, but political considerations at present stand in the way of a European spending much time in the neighbourhood of the independent hill tribes in that quarter.

## ON THE DISCOVERY OF A CELT OF PALÆOLITHIC TYPE IN THE PUNJAB, *by* W. THEOBALD, *Geological Survey of India.*

The celt, to which this notice refers, is interesting, as being the first specimen of these articles yet discovered in the Punjab, so far as I am aware 'Chips' and 'scrapers,' and remarkably fine 'cores' of chert, have been found in Sind, but no larger implements. The present celt is composed of a pale homogenous limestone, probably of nummulitic age, and presents a surface much corroded by exposure to the atmosphere, the stone of which it is composed being evidently of a character to suffer materially from such exposure The shape, however, of the article and the peculiar sinuous edge, the result of chipping from alternate sides, leaves no doubt as to its artificial character. It is, however, so rudely formed, that many similar specimens might escape observation, save to the practised eye of one familiar with such objects, and it is hoped that the present notice of this 'find' may result in the discovery of other specimens. It was picked up by myself on February 21st, 1879, on the surface of the ground, exactly opposite the village of Shodipur, on the Indus, 25 miles as the crow flies in a south-west direction below Attock. On showing the specimen to Kishen Singh, of the Geological Survey, he informed me he had once picked up a similar article near Rhotas, but being in doubt as to its character, had thrown it away again. This was unfortunate, but I mention the circumstance to direct the attention of future observers to the probable occurrence of these articles in other parts of the Punjab

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## PALÆONTOLOGICAL NOTES FROM THE KARHARBARI AND SOUTH REWAH COAL-FIELDS, *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

At end of last March and beginning of April, I had an opportunity of re-visiting the Karharbári coal-field, and, thanks to the kindness of Mr. W. G. Olpherts, C.E., F.G.S., the present manager of the East Indian Railway Company's Collieries, and to the assistance of Mr. N. Miller, Inspector at Passerabhia, I could collect further information regarding the comparison of the seams and the flora at the various places, supplementary to the views advanced in my Talchir-Karharbári flora.[1] I had the good fortune to collect numerous fossils from the second seam, from which none were hitherto known. As will be seen hereafter, this flora differs to a certain extent from that of the lower seam, and it would therefore appear that, although the parting between the second and the bottom seam is only thin, they have to be considered as distinct. I also obtained specimens from the other seams, so it will be well to say a few words about each of them. I shall do so in ascending order.

### 1. No. 1 *seam—bottom seam.*

Fossils from this coal seam are enumerated in my flora from eight places,

[1] Pal. Indica, Ser. XII, pt. 1, 1879.

three in the Serampur area,[1] and five in the Karharbári area[2] of the field. They come out of the shales in the roof of the seam.

It is this seam which has the greatest number of the peculiar fossils, and is most closely connected with the Talchir group. Of the common Damuda fossils we find *Glossopteris*, only rarely, and of *Vertebraria*, only two very small fragments were met with at one locality, No. 5D shaft, Passerabhia.

During my recent visit to the field, I did not collect many fossils from the bottom seam, but I happened to discover, amongst other rock specimens lying at the manager's office at Giridi, two nice specimens of fossils which Mr. Olpherts was kind enough to present to our Museum.

One of the specimens is from the bottom seam (No. 5D shaft) at Passerabhia (Karharbári), the other from the same seam (No. 11A shaft) at Buriadi (Serampur).

I also secured other duplicate fossils from these two shafts.

There are amongst them—

*Neuropteris valida*, Fstm., from both shafts.

*Nöggerathiopsis hislopi*, Fstm., also from both shafts.

Of this latter the two specimens presented by Mr. Olpherts are very large leaves, the largest we at present know from India; they will be figured in a supplemental fasciculus to the Talchir-Karharbári flora of the Palæontologia Indica; the specimen from Buriadi is almost complete, the basal portion only being broken off, while the apical portion is perfect. The Passerabhia specimen is although almost as large as the former, not so complete, a good deal of the apical portion being wanting; it shows, however, quite well the characters of the species, and must originally have been of a very large size.

The sections of these two shafts, showing the position of the fossiliferous shale, have been given in my Talchir-Karharbári flora,[3] to which I now refer.

I have picked up a few fossils at a new locality, No. 5 shaft, Jogitand, which also works the bottom seam. I give the section in descending order[4] —

*No. 5 shaft, Jogitand.*

| | | | |
|---|---|---|---|
| Soil | 1′ | | |
| Sandy brown clay | 38′ | | |
| Sandstone | 18′ | | |
| Strong dark shale | 5′ | 9″ | |
| Sandstone | 47′ | 3″ | |
| Strong dark shale with bands of coal (includes representative of 2nd seam) | 5′ | 3″ | Fossils from the base of this band. |
| No. 1 seam: coal | 12′ | | |
| Total | 127′ | 3″ | |

[1] Buriadi (11A); Chunka (Nos. 16 and 16G shafts).

[2] Passerabhia (Nos. 5D and 5G shafts); Matbadi (No. 1); Jogitand (No. 2) Domanighât.

[3] Pal. Indica, Ser. XII, pt. 1, pp. 36, 39.

[4] This and the two following sections were kindly supplied by Mr. W. G. Olpherts.

The fossils found represent, however, one species only:—

*Nöggerathiopsis hislopi*, Fstm.

The position of the fossiliferous band is the same as in No. 2 shaft Jogitand (*l. c.* pp. 42, 43); three species were named from this latter shaft, which are those of the bottom seam elsewhere.

We now know, therefore, fossils from the bottom seam from the following places:—

| | |
|---|---|
| Karharbári area. | Passerabhia, shafts No. 5D, No 5G; Máthadi, shaft No. 1; Jogitand, shafts No. 2, No. 5; Domahni ghat |
| Serampur area. | Buriadi, shaft No. 11A; Chunka, shafts No. 16 and No 16G |

The thicknesses of the bottom seam at the respective places are—

11′ (including 3′ partings), 11′ (including 3 partings), 13′, 8′, 12′, 9′, 14′, 9′, 12′ 6″.

The coal belongs to the lowest hitherto known in India, and owes perhaps to this circumstance its superior quality

*No. 2 seam.*

Already in my Flora of the Talchir-Karharbári beds (*l. c.* pp 39, 40) when quoting the sections of shafts Nos. 5D and 5G (Passerabhia), I indicated the existence of a second seam above the bottom seam, separated from this latter at both places by a 2′ 6″ parting of laminated sandstones and shales, in which the fossils of the bottom seam were found; the coal measured 7′ 2″ and 7′ respectively; both seams are worked together at these places.

At Jogitand this second seam is much thinner, being 2′ 6″ in No. 2 shaft, and being represented by dark shale in No. 5; the parting of black shale at No. 2 is 2′ 5″ thick.

At Máthadi the second seam is represented by only very thin bands of coal, separated by 6′ 7″ sandstone and shale from the bottom seam. At Domahni ghât are two outcrops of coal, one of which is the second seam; in the Serampur area there is also another seam close above the bottom seam which measures at Buriadi (shaft 11A) 2′ 6″, at Chunka (shaft 16) 7′ 6″, and (shaft 16 G) 6′, being separated from the bottom seam by 3′ 3″, 12′ 6″, and 6′ 6″ sandstone and shale partings, from which latter the fossils were procured, by which the lower seam here was correlated with the same in the Karharbári area.

No fossils were up till lately known from the layers above the second seam, the reason of which certainly lies in the overlying rock at the places mentioned consisting of sandstone only, which is very badly adapted for preservation of plants.

During my recent visit, however, I just came in time to collect fossils at two pits which work the second seam separately, the bottom seam being not reached yet, or not cut through, so that I am now able, for the first time, to introduce fossils from the second seam; the two shafts are in the Karharbári area, at Passerabhia, and their numbers are, No. 24 (29 new) and No. 40 (33

new). I shall name the fossils from each separately, quoting also the sections of the shafts to show the position of the fossiliferous band.

*No. 24 (29 new) shaft, Passerabhia*

*Section.*

| | | | |
|---|---|---|---|
| | Soil and brickwork | 31′ 1″ | |
| | Sandstone | 111′ 1″ | |
| | Coal | 1′ 9″ | |
| | Sandstone | 2′ 1″ | |
| | Coal | 2′ 8″ | |
| | Sandstone | 15′ 6″ | |
| | Coal | 1′ | |
| | Sandstone | 7′ 8″ | |
| | Shale | 7″ | Fossils found in this band. |
| 2ND SEAM | *Coal* | 1′ 3″ | |
| | Carbonaceous shale | 2″ | |
| | Coal | 9 | |
| | Soft, laminated bright coal | 2″ | |
| | Coal | 3′ 4″ | |
| | Carbonaceous shale | 5″ | |
| | Burnt coal (by trap) | 1′ 7″ | |
| | Bottom seam not reached. | | |
| | TOTAL | 184′ 7″ | |

The thickness of the seam is therefore 7′ 8″, with 7″ partings of shale, which corresponds well with the thickness of the second seam in the sections of shafts Nos. 5D and 5G[1] (Passerabhia).

The fossiliferous band in the present shaft is the 7″ shale above the coal.

It is very dark grey, very close, shale crowded with fossil leaves, which partly are in so close layers that it is difficult to get an entire leaf.

The fossils are—

*Glossopteris communis*, Fstm. Very numerous.
*Gangamopteris cyclopteroides*, Fstm.
*Nöggerathiopsis hislopi*, Fstm. Rare.

*Shaft No. 40 (33 new), Passerabhia.*[2]

*Section.*

| | | |
|---|---|---|
| 3RD SEAM | Soil and brickwork | 9′ 6″ |
| | Sandstone | 18′ 3″ |
| | Coal | 7′ 11″ |
| | Sandstone | 19′ 4″ |
| | Shale | 1′ 2″ |
| | Sandstone | 82′ 1″ |
| | Carried over | 138′ 3″ |

[1] Pal. Indica, Ser. XII, pt. 1, 1879, pp. 39, 40.

[2] This section is also otherwise of interest, showing the position of all the three seams of this area.

| | | | |
|---|---|---|---|
| | Brought forward | 138′ | 3″ |
| | Dark sandstone | 4′ | 11″ |
| | Sandstone | 11′ | 10″ |
| | Stony coal | 2′ | 8″ |
| | Sandstone | 10′ | 9′ |
| | Stony coal | | 6″ |
| | Sandstone | 17′ | 1″ |
| | Shale (fossiliferous) | | 10″ |
| 2ND SEAM | *Coal* | 1′ | 10″ |
| | Carbonaceous shale | | 2″ |
| | *Coal* | 1′ | 1″ |
| | Burnt *Coal* | 4′ | |
| | Trap | | 1″ |
| | Charred *Coal* | 1′ | 1″ |
| | Sandstone | | 11″ |
| | Carbonaceous shale | 2′ | 7″ |
| | Sandstone | | 10″ |
| | Shale | | 4″ |
| 1ST SEAM | Bottom seam, stony and burnt (Seam not cut through) | 3′ | |
| | TOTAL | 202′ | 4″ |

The fossils at this locality were more various, and are preserved partly in a dark fine, grained shale, and partly in a more sandy rock. They are—

*Schizoneura ?* (probably ? *gondwanensis*)—two specimens, rather badly preserved, but showing apparently an arrangement of leaflets like in *Schizoneura*, with dissolved sheaths.

*Equisetaceous* stalks. These are very numerous, and all of the same kind, *i.e.*, very broadly ribbed, ribs and furrows in juxta-position. They are presumably the stalks and stems of the same plant, to which the above-mentioned leaved specimens belong, probably *Schizoneura*.

*Vertebraria indica*, Royle.—Several specimens of the real Damuda form; also branched specimens.

*Gangamopteris cyclopteroides*, Fstm.—The common form.

*Glossopteris communis*, Fstm.—Several specimens.

*Glossopteris* sp.—A more oval leaf, with comparatively a very long stalk.

*Nöggerathiopsis hislopi*, Fstm.—Several specimens, both in the dark shale and in the more sandy variety.

*Seeds.*—Small, slightly winged, belonging perhaps to *Nöggerathiopsis*.

Taking now these fossils and those from No. 24 into close consideration, we find that although the second seam is separated from the bottom seam by a comparatively thin band only, yet the flora has a slightly different character. *Vertebraria* becomes more numerous, and *Glossopteris*, although representing only

one or two species, occurs in greater numbers. Two not very favourably preserved specimens appear to represent *Schizoneura gondwanensis*, Fstm.

No fossils were found as yet from the seam above the bottom seam in the Serampur area, but the correlation of the second seam in the Karharbári area, with that in the Serampur area, is apparently correct, the bottom seams in both areas being the same.

### *The 3rd seam, Passerabhua.*

There is not much new to be reported from the 3rd seam area (*l. c.* p. 40) I have obtained a few specimens from shaft No. 17 B[1] which represent a species already known from this place, *viz.*, *Noggerathiopsis hislopi*, Bunb; some specimens indicating very large leaves.

From shaft No. 17 C I have obtained one specimen which contains three forms new for this place and therefore for the 3rd seam.

*Gangamopteris* comp. *angustifolia*, Mc'Coy.—One leaf.

*Winged seeds.*—Of the same kind as that one figured by me from Buriadi[2] and known also from Mohpáni. Similar seeds, but smaller, are also known from the Damuda and Panchet division. I take them to represent the genus *Samaropsis* (comp *parvula*, Heer and Schmalhausen).

*Seed.*—Another large seed also was found Of this I can form no idea at present, but I shall figure it with all the other new forms in a supplement to the Talchir-Karharbári flora.

This third seam appears to be developed in the northern portion of the Karharbári area only.

### *No. 4 seam, the "hill-seam."*

In my already-mentioned paper I also mentioned the seams on the Komaljore and Bhuddua hills, classing them as a 4th seam, and judging from some fossils found on the Komaljore (Lumki) hill, and from the very much higher position of the seam, I represented them as belonging most probably to the Damuda division. No fossils were known from the Bhuddua hill. This time, however, I collected some fragments from above the coal; they are *Glossopteris*; they are of course at present quite insufficient for any conclusive decision, but I think there are stratigraphical points enough which, in combination with the fossils from the Lumki hill, show that it is an independent seam.

Bali hill in the western portion of the field is another place where this "hill seam" is represented. I have not yet examined this locality, but intend to do so on the first opportunity, as it is probable that more fossils may be found there, from which the horizon may be better fixed.

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[1] The sections of this shaft, as well as of the other one, No. 17 C, are described in my Talchir-Karharbári flora, *l. c.* p. 40-42, where I also named the fossils.

[2] Ibidem, Plate XXIV, fig. 5.

The relations of the various seams may be shown in the following tabular list —

| DIVISION | Number of seam | Western portion | Karharbari portion | Serampur portion | FOSSILS |
|---|---|---|---|---|---|
| Damuda Division | 4th | Hill seam on Bali Hill | 'Hill seam' on Bhuddua, fragments of fossils (*Glossopteris*) | "Hill seam on Tunki Hill, a few fossils | Named in my Talchir Karharbari Flora, p 44 *Sphenopteris polymorpha*, Fstm worthy of notice Barakars |
| | | ? | About 200′ sandstone down to the next seam | ? | |
| Talchir Division | 3rd | The outcrop of seams at Gopar dihi, Topsadih and Satighat, in Khakoo Laver | 3rd Seam at Passeribhia No 17B and 17C shafts | | Named l c, same page Bendes *Gangamopteris angustifolia*, McCoy *Samaropsis* comp *parvula* Heer seed Karharbari beds |
| | 2nd | | 2nd seam at Passeribhia (No 24 and 40 shafts) Mathadi Jogitand and Domahini Fossils known from the first place. | 2nd seam at Buriadi and Chunka | Identified now for the first time — *Schizoneura ? gondwanensis* Fstm, *Equisetaceous* stems, *Vertebraria indica*, Royle, *Gangamopteris cyclopteroides*, Fstm *Glossopteris communis*, Fstm, (rather numerous) *Glossopteris* another sp, *Noggerathiopsis hislopi*, Bunb sp (Feistm), seeds Karharbari beds. |
| | 1st | | Bottom seam at Passeribhia (No 5D, No 5 J) Mathadi (No J) Jogitand (No 2 and 5), Domahni | Bottom seam at Buriadi (No 11A) and Chunka (No 16 and 16G) | Named in the above work, p 44. Of interest, the two large leaves of *Noggerathiopsis*, Fstm procured this time Karharbari beds |

Talchir Group

## PALÆONTOLOGICAL NOTES FROM THE SOUTH REWAH COAL-FIELD.

From this extensive coal-field there were hitherto comparatively very few fossils known. Those we possessed were plants only, and belong to two collections; of the one made in 1861 by Mr. J. G. Medlicott the specimens were labeled "South Rewah" and "Sohágpur;" the former designation corresponds with what now will be distinguished as the Gopat river area, while the latter name will be retained.

Another collection, sent by Mr. C. A. Hacket, 1872, contains a few fossil

plants from the Son river, west of Garara, a place that is also represented in the collections received recently from Mr. Hughes.

From those fossils and their equivalents elsewhere I had judged that they represent the Raniganj (Kámthi) group, an opinion which the subsequent collections have confirmed.

Since October last a regular survey of this field was begun by Mr. Hughes, who has already been fortunate enough to procure a large number of interesting fossils, both vegetable and animal, which are of great importance for fixing the horizon of the beds.

Mr. Hughes has sent two collections; the first contained plants from the Lower and animals from the Upper Gondwánas. The former I was able to include in the list of localities in my paper (now in the press) on the Damuda-Panchet flora[1]; they all were of the Raniganj (Kámthi) horizon, while the animal remains were of the Maleri horizon of the Central Provinces.

The second collection contained Lower and Upper Gondwána plants, many of great interest; it arrived too late to enable me to insert the localities of Lower Gondwána fossils in the alphabetical list in my detailed work.

This collection was much larger, and contained fossils from many more horizons, also several new species of plants. In anticipation of full description and illustration I may now give a brief notice of them, so far as they are known with certainty. I shall enumerate them according to the horizons, and within each horizon from each locality The horizons I have put down as Mr. Hughes has provisionally indicated them on his labels; two localities for which there was no horizon indicated, I have placed to such horizons as would be assigned to them by the fossils when compared with already-established classifications. I also include the older collections made by Mr. J. G. Medlicott and later by Mr. C. A. Hacket.

## A.—LOWER GONDWANAS.

### I. TALCHIR DIVISION.—*Talchir group.*

*Goraia*, on the Johilla river, near Páli, Singwara district.

*Collectio* Hughes, 1880.

*Equisetaceous* stem.—One specimen only, with a fragmentary stem, showing a fine ribbing on the surface, but no joint; may be equisetaceous.

### II. DAMUDA DIVISION.

#### *a. Bardkar group.*

*Páli* and *Johilla* rivers (junction of), near Páli.

*Collectio* Hughes, 1880.

*Glossopteris communis*, Fstm. Of the usual type.

*Gangamopteris cyclopteroides*, Fstm. There is one leaf which I cannot distinguish from this species.

[1] Pal. Indica, Ser. XII, pt. 2.

*Nöggerathiopsis* (? Rhiptozamites) *hislopi*, Bunb. sp (Fstm.) Numerous leaves of various sizes.
*Seeds*, small, slightly winged

I must confess that this flora, small as it may appear, reminds me more of that of the 2nd and 3rd seams of the Karharbári coal field (Karharbári beds) than of the typical Barákar group. When Mr. Hughes next season takes up work again, he will probably succeed in procuring a few more fossils which may decide the question; in the meantime they may remain with the Barákar group.

### b. *Raniganj group* (and Kámthis).

With this group I include also those localities which Mr. Hughes marked Kámthis. Here also are placed the fossils collected previously by Messrs. J G Medlicott and C. A. Hacket. I name first the localities from the northern portion of the field, from the Gopat river area; these constitute also the lower Gondwána fossils of the first collection sent by Mr. Hughes in March 1880 Then follow those in the Sohágpur district.

#### a. *Gopat river area.*

*Bajbai*, 2 miles west of Gopat river, lat. 24° 4′, long. 81° 57′.

*Collectio* Hughes, 1880.

*Schizoneura gondwanensis*, Fstm. Just like the same from the typical Raniganj group, Raniganj field.
*Vertebraria indica*, Royle. Many nice specimens.
*Glossopteris communis*, Fstm.
*Glossopt. indica*, Schimp.
*Glossopt. angustifolia*, Bgt.

*Chanduidol*, about 8 miles west-north-west of Bajbai, and about 3 miles west of Marhwás.

*Collectio* Hughes, 1880.

*Schizoneura gondwanensis*, Fstm. Typical Raniganj form.
*Glossopteris formosa*, n. sp. Raniganj species.

*Mahán river* (tributary of Gopat river), between Minarra (Mirhara) and Gaja (Ganjar), lat. 23° 57′, long. 81° 58′.

*Collectio* Hughes, 1880.

*Schizoneura gondwanensis*, Fstm. Typical Raniganj form.
*Glossopteris communis*, Fstm.
*Glossopt. angustifolia*, Bgt.
*Alethopteris* comp. *whitbyensis*, Göpp. I have no means to distinguish this fern from the jurassic species.
*Angiopteridium*.—Two fragments of a *taeniopteroid* fern resembling a similar one in the Kámthi beds of the Nágpur area, which I quoted as *Angiopt.* comp. *m'clellandi* O. M.

*Mahán river*, near Minarra (close to the former locality).

*Collectio* Hughes, 1880.

*Schizoneura gondwanensis*, Fstm. Typical Raniganj form
*Glossopteris communis*, Fstm.
*Glossopt. indica*, Schimp.
*Glossopt. retifera*, Fstm. Raniganj form.
*Glossopt. angustifolia*, Bgt.
*Alethopteris* comp. *whitbyensis*, Gōpp. As above.

*Mahán river*, near Tansar, close to junction with Gopat river, north of the preceding locality.

*Collectio* Hughes, 1880.

*Vertebraria indica*, Royle.
*Glossopteris* sp.

*Parasi*, west of,—from stream running between Parasi and Kunjwar, about 5 miles east of Gopat river, lat. 24° 2″, long. 82° 7″.

*Collectio* Hughes, 1880.

*Glossopteris*, sp. Fragments

With this area also those fossils contained in our collections have to be included which were collected by Mr. J. G. Medlicott, 1861, and are labelled "South Rewah." The fossils are—

*Vertebraria indica*, Royle.
*Stems.*
*Glossopteris communis*, Fstm.
*Nöggerathiopsis hislopi*, Bunb. sp. (Fstm.).
*Voltzia heterophylla*, Bgt. The determination of this species from this coal-field is now confirmed by Mr. Hughes' recent specimens.
*Small seeds.*

These fossils, however, correspond very much with those of the next following locality, in the Sohágpur district.

*β. Sohágpur District.*

*Hardi*, near—about 15 miles south-east-south of Sohágpur, long. 81° 30′, lat. 23° 6″.

*Collectio* Hughes, 1880.

*Vertebraria indica*, Royle.
*Glossopteris communis*, Fstm.
*Nöggerathiopsis hislopi*, Bunb. sp. (Fstm).
*Voltzia heterophylla*, Bgt. Several leaved branchlets, which leave no doubt about this species.
*Samaropsis* comp. *parvula*, Heer. Winged seeds, known also from other places.

*Kachodhar*, about 11 miles west of Sohágpur.

*Collectio* Hughes, 1880.

*Glossopteris communis*, Fstm. One leaf peculiarly folded.

*Sohágpur*, in South Rewah

*Collectio* J. G. Medlicott, 1861

*Vertebraria indica*, Royle.
*Glossopteris communis*, Fstm.
*Glossopteris browniana*, Bgt.
*Glossopteris damudica*, Fstm.

*Son river*, west of Garari, Sohágpur district

*Collectio* Hacket, 1872

Fossils in a dark greenish-grey sandy shale. Considering the fossils, I placed this locality with the Raniganj (Kámthi) group, which now by Mr. Hughes' fossils from the same locality (see next locality) is further confirmed.

The fossils were—

*Vertebraria indica*, Royle.
*Macrotaeniopteris feddeni*, Fstm. Like the same in the Kámthis of the Nágpur area.
*Glossopteris communis*, Fstm.
*Dictyopteridium* (?) sp.

*Son river*, near Gúráru (as written by Mr. Hughes—Gurarn on the Indian Atlas) about 1 mile east of Son river, long. 81° 23′, lat. 23° 28′.

*Collectio* Hughes, 1880

This is evidently the same locality as that above mentioned of Mr. Hacket. Mr. Hughes' fossils are in two kinds of shale, one dark greenish-grey sandy, like in Mr. Hacket's specimens; the other light yellowish-grey soft clay-shale.

*a.*—Dark greenish-grey shale—

*Schizoneura gondwanensis*, Fstm. Raniganj type.
*Glossopteris communis*, Fstm.
*Glossopteris indica*, Schimp.
*Squamæ gymnospermarum*.

These fossils leave no doubt about the Raniganj horizon of this bed, as determined already before by me from Mr. Hacket's specimens.

*b.*—Light yellowish-grey shale.

*Glossopteris angustifolia*, Bgt.
*Rhipidopsis*, n. sp., like in the Kámthis on the South Godávari (Kunlachera, originally a genus in the Russian Jura of the Petschora country).

*Son river*, opposite Sarsi.

*Collectio* Hughes, 1880.

*Schizoneura gondwanensis*, Fstm. Very big leaves (or, better said, portions of the leaf sheath).
*Glossopteris browniana*, Bgt.

These fossils leave indeed no doubt as to the establishment of the typical Raniganj group in this region, as is especially illustrated by the numerous occurrence of *Schizoneura gondwanensis*, Fstm., and several species of *Glossopteris*,

occurring mostly in the Raniganj group. We can in fact say, *Schizoneura* is the characteristic feature of these localities in South Rewah, and is more widely distributed here than *Vertebraria*, as out of eleven localities, *Schizoneura* occurred in six and in great numbers, while *Vertebraria* was found only at five localities. Of other fossils I would specially point out the following —

*Macrotæniopteris feddeni*, Fstm. } both of the typical Raniganj
*Glossopteris formosa*, n. sp., *retifera*, Fstm., } group.

*Alethopteris*.—There are two pinnæ of an *Alethopteris* which has to be referred to the group of *Al. whitbyensis*, Gopp. A fragment of an *Angiopteridium* has to be referred to *Ang. mc'Clellandi*.

*Voltzia heterophylla*, Bgt, which we already know from the Karharbári beds, is here again represented in the Raniganj group, and not rare.

*c. Supra-Damudas.*

On the labels of several fossils from two localities Mr. Hughes has indicated the horizon as "Supra-Damudas." To judge, however, from the fossils and from petrographical character of the specimens, the fossils indicate lower Gondwánas, although representing perhaps two horizons.

*Daigaon*, on the Johilla river, about 4 miles north-west of Páli.

*Collectio* Hughes, 1880.

*Vertebraria indica*, Royle.

According to our present knowledge, *Vertebraria* is especially typical of the Damuda division,[1] and in default of other fossils, I would consider this locality to belong to this division; it may be Raniganj (Kámthi) group

*Parsora* (south tolah), near Beli, about 6 miles north-north-east of Páli.

*Collectio* Hughes, 1880.

The fossils from this locality are very interesting, especially one new species They are preserved in a red-brown, highly ferruginous, micaceous shale, completely agreeing with the rock in which Mr. V. Ball's fossils from Latiahar, in the Auranga coal-field, are preserved, which as to the horizon[2] were left undecided, although Mr. Ball thought that they are probably "Mahádevas." Considering, however, the fossils, amongst which there is *Vertebraria* and *Glossopteris*, I treated this locality[3] as belonging to the Panchets, and it might be the same case with the present locality in South Rewah, and the more so as the fossils would perhaps support that view.

The fossils are—

*Danæopsis*.—A new species—in numerous specimens.

Of this genus there were hitherto known with certainty only two species,

[1] There are several specimens known from the Karharbari beds of the Karharbári coal-field and also from a doubtful locality in the Auranga coal-field, which probably is Panchets, but, as a rule, it is a fossil of the Damudas.

[2] Ball, Mem. Geol. Survey of India, Vol. XV, pt. 2, p. 89.

[3] Pal. indica, Ser. XII, pt. 2, p. 3. (to be issued shortly.)

*D. marantacea*, Heer, from the German Keuper (Upper Trias), and *Danæopsis rajmahalensis*, Fstm., from the Rájmahál group in Bengal (Rájmahál hills). The present species differs from both. It is a much larger form than *D. rajmahalensis*, Fstm., as is especially seen from the thickness of the rhachis and the midribs of the pinnulæ; the veins also have another direction in *D. rajmahalensis*, passing out at a more acute angle from the rhachis and running straighter to the margin. *Danæopsis marantacea*, on the other hand, is again bigger than our present species, the whole frond appears much larger, the pinnulæ longer, the midribs thicker, and especially the top pinnulæ much larger. There are two specimens in Mr. Hughes' collection, showing the top pinnula, which is shorter than the other pinnulæ, while in *Dan. marantacea*, Heer, the top pinnula was equal in size to the others. I refer especially to Schimper's figure Tr. d. Pal. végét. Pl XXXVII. The secondary veins in *Dan marantacea* agree well with those in our present species.

But there is an important character in our present species of *Danæopsis; the primary rhachis* of the frond is *dichotomously forked*, as is shown distinctly by about six specimens; the pinnulæ at the beginning of the fork on the inner side being represented by lobes only. Below the furcation the pinnulæ are also only small. We shall have to take this present species as intermediate between *D. rajmahalensis*, Fstm., and *D. marantacea*, Heer, with closer relation to the latter. All other details will be given subsequently with illustrations. It will be described as *D. hughesi.*

*Thinnfeldia* comp. *odontopteroides*, Moor. sp. There are three fragments of fronds, with forked rhachis, which have entirely the aspect of *Thinnfeldia odontopteroides*, Moor. sp. A similar fern was already brought by Mr. Griesbach from the Panchets of the Ramkola coal-field, and this plant would be a support for the view of the locality under discussion being of the same horizon.

*Neuropteridium*, sp. There is a portion of a frond which appears to be single pinnate and belongs to Professor Schimper's triassic group of *Neuropteris*, distinguished as *Neuropteridium*. We know already one species from the Karharbári beds. The present one appears to be different.

*Nöggerathiopsis hislopi*, Bunb., sp. Portions of large leaves. This species is known from the whole Talchir and Damuda division.

This is certainly a very interesting association of forms, but it no doubt shows that this locality has to be considered as belonging to the Lower Gondwánas, probably Panchets, but *Danæopsis* would be another form helping to bridge over the break between the lower and upper Gondwánas.

## B.—UPPER GONDWÁNAS.

### (a). MALERI BEDS.

The most important discovery made by Mr. Hughes is, I think, that of the Maleri horizon (of the Godávari basin) in South Rewah. It is undoubtedly established by numerous bones of land animals, the same as those in the Central Provinces.

*Tiki*, about 6 miles south of Beohari, long. 81° 25', lat 23° 56'

*Collectio* Hughes, 1880.

*Parasuchus hislopi*, Huxley (MSS.) represented by portions of jaws, several teeth, numerous fragments of dermal scutes, vertebræ, and other bones. They represent an animal about equal in size to that of the Maleri beds in the Central Provinces.

*Hyperodapedon*, sp. Jaws, apparently of the same animal as that of the Central Provinces, but three of the jaws are larger than any hitherto known from the latter place.

*Unio*, sp. Several specimens of a small Unio-like shell also occur.

### b. JABALPUR GROUP

There is another horizon of importance in this coal-field, as it contains besides most of the Jabalpur plants of the Sátpura basin, also others, and especially one species characteristic of, and hitherto only known from, the intermediate beds[1] of the upper Gondwánas on the south-east coast of India.

*Bansa*, on the Machrar river, about 6 miles south-west of Chandia.

*Collectio* Hughes, 1880.

*Alethopteris whitbyensis*, Gopp. Typical form.

*Alethopteris indica*, O. M. Probably only a larger variety of the former.

*Alethopteris medlicottiana*, Fstm. The same typical form as from near Jabalpur.

Besides these, there are three other ferns which require further examination.

*Podozamites lanceolatus*, L. & H. Numerous specimens.

*Ptilophyllum cutchense*, Moor., in dark sandy shale, resembling similar shales from the Sher and Hard rivers.

*A cycadeaceous* fruitleaf?

*Taxites tenerrimus*, Fstm., a Jabalpur group species.

*Taxites planus*, Fstm. At first described from the Ragavapuram shales, the Sripermatur group, and the Vemáveram shales, now here represented by several specimens, one a very fine one. I think we have to consider this species as surviving from these intermediate beds on the south-east coast into the Jabalpur group of South Rewah; it is not met with in the Jabalpur group of the Sátpura basin.

*Brachyphyllum mammillare* L. & H., completely the same form as in the typical Jabalpur group near Jabalpur.

*Echinostrobus rhombicus*, Fstm.

*Araucarites cutchensis*, Fstm. The same as in Cutch and the typical Jabalpur group.

*Gingko*, sp., a small leaf with a thin stalk

Some other coniferous branches.

It will be very interesting to learn from Mr. Hughes' descriptions in what relation is Jabalpur group is to the Maleri beds of Tiki.

To make this list of fossils from South Rewah complete, I have still to quote

[1] Ragavapuram shales, Sripermatur group, Vemáveram shales.

a few fossils which in 1872 were brought by Mr. Hacket. They were already mentioned, and some figured in my Jabalpur Flora[1] and referred to as from "South Rewah." I have since found a label referring to these South Rewah fossils and giving some information as to the locality.

*Chandia*, small nadi south of,—South Rewah, Singwara district.

*Collectio* Hacket, 1872.

1877. Feistmantel, Flora of the Jabalpur group, etc., Pal. Ind., IX., 2.

*Alethopteris medlicottiana*, Fstm., a small specimen not mentioned in my Jabalpur flora, found subsequently, will be figured together with Mr. Hughes' specimens.
*Sagenopteris ?* sp.,[2] Feistm., *l. c.*, p. 10, Pl. III, fig. 6.
*Podozamites lanceolatus*, L. & H., *l. c.*, p. 11, Pl. III, figs. 7, 8, 11, 12.
*Podozamites spathulatus*, Fstm., *l. c.*, p. 12, Pl. IV, figs. 11, 12.
*Araucarites cutchensis*, Fstm., *l. c.*, p. 16, Pl. XIV, figs. 11—13.
*Echinostrobus expansus*, Schimp., p. 17, Pl. XI, fig. 5.
*Ech. rhombicus*, Fstm., *l. c.*, p. 18, Pl. XI, figs. 6—11.

## FURTHER NOTES ON THE CORRELATION OF THE GONDWÁNA FLORA WITH OTHER FLORAS *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

### *Flora of the Kusnezk basin and Tunguska river, Siberia.*

In a short note in the first number of this year's Records with reference to a preliminary paper of Mr. Schmalhausen on the jurassic flora of the Kusnezk basin and Tungska river, I compared the Indian (and Australian) leaves formerly known as *Nöggerathia*, but distinguished by me as *Nöggerathiopsis*, with the Siberian *Rhiptozamites* Schmalh, which also had at first been described as *Nöggerathia*. I have since received Prof. Schmalhausen's work, illustrated with sixteen plates,[3] and I would now complete my reference to his observations.

My supposition of our *Nöggerathiopsis* and the Siberian *Rhiptozamites*, Schmalh. being in closest relation is now confirmed. The size and form of the leaves and the characters of the veins is in both genera completely identical; the only difference between them being that the veins in *Rhiptozamites* are closer. This character might eventually be taken as a specifical distinction only, while yet the two genera might be identical. This of course is not necessarily of much consequence regarding the correlation of the two formations in which these genera are found; but their close generical relation (perhaps identity) is of great importance in fixing the systematical position of the one from the other.

Prof. Schmalhausen places his *Rhiptozamites*[4] (which name by itself implies the

[1] Pal. Indica, Ser. IX, pt. 2.
[2] In the paper quoted the locality of this fossil is by mistake given as Jabalpur instead of South Rewah.
[3] Beiträge zur Jura-Flora Russlands, von Joh. Schmalhausen, in Mém. de l'Acad. Impér. des Sc. de St. Petersbourg VII, Ser., Tome XXVII, No. 4.
[4] ῥίπτω, to cast off, and Zamia—botanical name.

cycadeaceous nature) with the *Cycadeaceæ*, together with well-known cycadeaceous genera, such as *Ctenophyllum*, *Dioonites*, and *Podozamites*; in the first instance these leaves (*Rhiptozamites*) which are described as pinnate (I used for the Indian leaves the expression *foliis biserialibus*), are compared with forms of *Podozamites*, as I also had done with the Indian leaves, before Prof. Schmalhausen's paper was in my hands.[1]

The Siberian leaves are described as deciduous, being generally found as single leaves; this certainly was also the case with the Indian forms, as all the leaves hitherto found were detached (*l. c.* p. 24).

Prof. Schmalhausen also points to the unequilateral shape of the leaves, adducing this as a character in favour of the view of the fronds having been pinnate, in which case the leaves generally met with would be the pinnulæ. A similar character had already been observed in the Indian leaves from the Nágpur area by Sir Ch. Bunbury, who expressed it by saying the leaves were "not symmetrical, but very slightly oblique," and I confirmed it subsequently from the Karharbári specimens (*l. c.* p. 24 and figures); it is seen also in all the specimens from the other localities, so that we may fairly use this character in support of the view that the detached leaflets belonged to a pinnate frond. Amongst the Indian specimens not one has been observed showing the connection with the stalk; but there are several specimens (from the Raniganj field, from South Rewah, and the Sátpura basin) which show such an association of two or three leaves as forcibly reminds us of an arrangement of the pinnulæ in a pinnate leaf.

With this close generical relation (eventually identity) of *Rhiptozamites* Schmalh. and *Nöggerathiopsis*, Fstm. in view, we are completely justified in placing these latter also with the order *Cycadeaceæ*, family *Zamieæ*, and have to compare them, as I have already done, with the fossil *Podozamites*, which is essentially a mesozoic and prominently jurassic genus, known in the Upper Gondwánas in India, in the Kusnezk basis in the Altai (in association with *Rhiptozamites*), and in the jura of E. Siberia and in the Amur countries; also numerous in Europe. This cycadeaceous plant, *Noggerathiopsis*, is rather numerous in the Lower Gondwánas; it occurs in—

| | |
|---|---|
| THE TALCHIR DIVISION ... | Talchir group: rare (Deoghur).<br>Karharbári beds: very numerous both in the Karharbári field (Nos. 1, 2, 3 seams) and in the Mohpáni coal-field. |
| DAMUDA DIVISION ... | Barákar group: Rámkola coal field, South Rewah coal-field, Sátpura basin (Shahpur and Umrét).<br>Raniganj (Kámthi): Raniganj coal-field (rare); South Rewah (frequent).<br>Nágpur district (Kámthis): numerous. |

This *Nöggerathiopsis* forms in the Lower Gondwánas just as prominent a feature as *Pterophyllum*, or *Cycadites*, or *Podozamites* does in the Upper Gondwánas, and consequently the great break between the Lower and Upper Gondwánas is

[1] Pal. Indica, Ser. XII, 1, p. 23.

now—as regards at least the *Cycadeaceæ*—to a great extent removed. This break is still more filled in by the interesting circumstance (to be noticed presently) that there are other forms, both in the Lower and Upper Gondwánas, which find their close analogies or identical representatives in the Jura of the Altai and Siberia and elsewhere.

Before proceeding to this point, the systematical position and analogies of *Nöggerathiopsis*, Fstm., may be therefore expressed thus—

CYCADEACEÆ

*a.* ZAMIEÆ

| *Noggerathiopsis*, Fstm | *Noggerathiopsis*, Fstm. | *Rhiptozamites*, Schmalh. | *Podozamites*, Br |
|---|---|---|---|
| Palæozoic—Australia (N. S. Wales). | Lower Gondwánas, India. | Jura—Altai and the Tunguska River. | Jura—(Upper Gondwánas,) in India, Siberia, and elsewhere. |

The jurassic flora described by Professor Schmalhausen from the Altai Mts and the Tunguska river,[1] is further interesting, as it contains several forms partly identical with and partly closely related to species in the Upper and Lower Gondwánas of India, representing thus, so to speak, an amalgamation of parts of both. Taking also the other jurassic floras of E. Siberia and the Amur countries (Heer) into consideration, we can establish the following list of correlations:—

| GONDWANA SYSTEM—INDIA. | JURA—SIBERIA, ETC. |
|---|---|
| *a* UPPER GONDWANAS. | |
| *Alethopteris whitbyensis*, Gopp. Kach and Jabalpur group; Sripermatur group (Sripermatur and Vemáveram). *Alethopteris indica*, Oldh. and Morr. Sripermatur and Rájmahál group. | *Asplenium whitbyense*, Heer (Siberia and Amur countries). |
| *Dicksonia bindrabunensis*, Fstm. Rájmahál group. | *Dicksonia concinna*, Heer. Amur countries. |
| *Podozamites lanceolatus*, Schimp. Jabalpur and Sripermatur group. | *Podozamites lanceolatus*, *eichwaldi*, etc. E. Siberia and the Altai. |
| *Anomozamites* (*Pterophyllum*) *princeps*, O. M. Rájmahál group. | *Anomozamites schmidti*, Heer. Amur countries. |
| *Anomozamites lindleyanus*, Schimp. Sripermatur group. | *Anomozamites lindleyanus*, Heer. E. Siberia. |
| *Gingko lobata*, Fstm. Jabalpur group. | *Gingko digitata*, Heer. E. Siberia and Altai. |
| *Czekanowskia ?* and *Phönicopsis ?* Jabalpur group. | *Czekanowskia* and *Phönicopsis*. Heer. Altai, E. Siberia, Amur countries. |
| *b.* LOWER GONDWANAS. | |
| *Phyllotheca indica*, Bunb. Raniganj (Kámthi) group. | *Phyllotheca sibirica*, Heer, and *Phyll. deliquescens*, Schmalh. (Göpp. sp.). Altai and E. Siberia. |
| *Stems* of the same. | *Stems*, quite similar (*See* Schmalhausen, *l. c.* Pl. I, fig. 2). Altai. |

[1] I leave the flora of the Petschora country out of comparison here, and refer to the Asiatic (Siberian) forms only.

| GONDWANA SYSTEM—INDIA—*contd.* | JURA—SIBERIA, ETC.—*contd.* |
| --- | --- |
| ***Phyllotheca robusta***, Fstm. Raniganj group (Rájmahál hills). | ***Phyllotheca schtschurowski***, Schmalh. Altai |
| ***Alethopteris whitbyensis***, Göpp. Raniganj group. ***Alethopteris lindleyana***, Royle. Raniganj group. | ***Asplenium whitbyense***, Heer. (Siberia, Amur countries) |
| ***Cyathea*** comp. ***tchihatcheffi***, Schmalh. Barákars. | ***Cyathea tchihatcheffi***, Schm., Altai. |
| ***Dicksonia hughesi***, Fstm. Raniganj group. | ***Dicksonia concinna***, Heer. Amur countries. |
| ***Glossopteris gangamopteris.*** Lower Gondwánas, (***Rubidgea***. Karoo beds, S. Africa). | ***Zamiopteris glossopteroides***, Schmalh. Altai, This fern resembles strikingly (and is also by Schmalhausen compared with) *Glossopteris* in shape and distribution of veins, but has no midrib and no anastomoses. Other specimens resemble *Gangamopteris angustifolia*, but they again want the anastomoses. The most closely related genus is *Rubidgea* from the Karoo beds; there is hardly any distinguishing character, but they are not to be mistaken for my *Palæovittaria*. |
| ***Nöggerathiopsis hislopi***, Fstm. Lower Gondwánas. | ***Rhiptozamites göpperti***, Schmalh. Altai, Tunguska. |
| ***Samaropsis*** comp. ***parvula***, Heer. Karharbári beds, Raniganj group (Bijori). Panchets. | ***Samaropsis parvula***, Heer. Altai (See Schmalh. *l. c.*, Pl. IV, fig. 3 *b*.) E. Siberia. |
| ***Squamæ gymnospermarum.*** Barákars and Raniganj group. | ***Squamæ gymnospermarum.*** Altai, Tunguska (Pl. XV, figs. 14, 15, represent forms of the Raniganj group, while Pl. XVI, fig 22, represents a Barákar form). |

This list speaks for itself, and there is nothing surprising in it when we consider the close relations of the various groups of the Gondwána system as independently observed. We have in addition the occurrence of *Glossopteris* in the Upper Gondwánas, the representation of *Podozamites* in the Upper, by *Nöggerathiopsis* in the Lower Gondwánas, the occurrence of *Glossopteris* and *Vertebraria*, in a horizon in the Auranga coal-field, which Mr. Ball could not assign to any bed of the Lower Gondwánas, but thought it should belong to the Máhadevas (Upper Gondwánas), although I think it may represent the Panchet group, etc. There is also a fine collection of plants made by Mr. Hughes in South Rewah, which will further illustrate this intermingling of the flora just on the boundaries between the lower and upper beds of the Gondwána system.

These relations, which no doubt will find further illustration in course of the more detailed work of the Survey, show well the fitness of combining all the beds from the Talchir group up to the Jabalpur and Kách group under one collective designation, for which the name *Gondwána system* was very happily chosen.

ADDITIONAL NOTE ON THE ARTESIAN WELLS AT PONDICHERRY, *by* W. KING, *Deputy Superintendent (Madras), Geological Survey of India.*

While my paper in the last number of the Records was in press, I received some further details from Mr. Poulain, giving corrected heights and discharges of water columns in the Savana and Úpallem wells, which were inserted in the body of the paper, but not in the introduction. Unfortunately I misunderstood some of these corrections, as they are explained in a later letter received from Mr. Poulain, and therefore it becomes necessary to draw attention to the following errors:—

On page 113, line 33, for 'three' read 6·5; for '44' read 30.
On page 114, line 16, for 'nearly 1 foot' read 3·28 feet.
On page 120, line 21, for '44,' read 30; for 'one' read six.

These corrections are made from a later note published in the '*Travaux des Commissions Locales*' which my friend Poulain has furnished since the publication of my paper, and of the existence of which I was unaware until now. A translation of this note is now appended; it follows as number five on the 'Experiences of Mr. Poulain' given in Appendix II of my paper.

*Experience at "Savana."*

"The latest information given on the progress of the borings up to the 11th September left the depth at 52·68 meters and the discharge at 90 litres a minute.

"The discharge increased proportionally with the disengagement of the sands at the bottom of the ascending column. It is now at 135 litres a minute. During the working the water had a very marked yellow-ochrey colour, and it became limpid as soon as the work was stopped. The actual depth is 53 meters.

"We have verified the hydrostatic level of this source, and as the ground surrounding our well has lately been raised by the heaping up of the excavated material, we have been obliged for exactness to take the level of the old soil. This having been ascertained, the rise is 1·96 meters above the soil. The water has not lowered from this point.

"Regarding the uses to which the water of the 'Savana' well may be applied, we cannot do better than reproduce in text the official analysis given by Mr. Castaing, Chef de Service Pharmaceutique, at the requisition of the Ordonnateur:—"Depth of the well, 52·68 meters. This water is limpid, colourless, inodorous, agreeable to the taste, and fresh. It contains 26 centigrammes of saline residue to the litre, composed of earthy chlorides and sulphates. It marks 7 degrees on the 'hydrotimètre.' It boils vegetables well, dissolves soap, and does not contain any organic matter. It possesses all the requisite conditions of a potable water, and is adapted for all culinary and industrial uses. It will leave only a feeble deposit in boilers if it be allowed to settle for a short time."

"From an agricultural point of view, and in the opinion of several native cultivators, the quantity of water now furnished by the well would be sufficient

for the cultivation of 12 cawnies of rice fields, or above double this superficies for inferior (*menus*) grain.

"The sinking of the tube will be continued for some meters more or so to penetrate further into the water sheet."

*Pondicherry, 30th September* 1877.

The search for these water sources is still being prosecuted at Pondicherry and in the neighbourhood, and this has been attended with fair success; but the Government boring in the Ville Noire is now in abeyance, as it was found impossible, with the appliances at hand, to drive the tube down beyond the depth attained, namely, about 550 feet, and there has been no further rise of water. It is proposed to run down a tube of smaller diameter, when opportunity offers.

In the meantime, a new well has been started by Government in the village of Ariankúpam, at about 300 yards from the south or right bank of the river of that name, which, however, is so far a failure also, though a rising sheet of water was tapped at a comparatively slight depth.

Here the level in the surrounding wells is at 16·40 feet below surface soil, perhaps about the mean level of Ariankúp river, which is tidal.

At 32·28 feet, water rose to a height of 3·83 feet over the surface soil. This water appears to have been the purest yet obtained in this way. After three days the discharge ceased, and the water disappeared from the tube Mr. Poulain conceived this might be attributable to accident; that the hole made by the borer was larger than the tube, and that the water had passed away between the latter and the surrounding deposits and been absorbed into permeable beds above, and on this he suggested to Government some means for meeting the mishap. The Engineer preferred to proceed with the boring and the sinking of the tube, and now a depth of 157 feet has been reached without a further water sheet having been struck.

The deposit latterly pierced is a clay or lithomarge of a reddish colour, with veins or streaks of white, such as is occasionally met with in the sandstones of Pondicherry and Cuddalore, below which, according to one account, is a conglomerate of a greyish colour and hard enough to be taken as an approach to beds of that series.

It is indeed very possible the Cuddalore sandstones may have been touched, or that the borer is close on them, it being not at all unlikely that a sub-alluvial ridge or plateau of these beds may exist at no great depth between the Ariankúp and Punear rivers, there being here a gap of rather unexplainable width in the red sandstone belt.

The general succession of beds in this boring is:—

1. Sandy soil and sands,
2. Thin band of black clay,
3. Whitish clay,

but this requires confirmation.

A private boring was put down some time ago at Mudeliarpet, a small village in the vicinity of the Colonial Gardens and the Savana filature, and a rising

these of water was tapped at 49 20 feet, which remained at nearly a foot below surface soil. The rise increased on the boring being carried deeper, and eventually stood at the level of the ground, which is, however, 1·47 feet above the surface level at Savana, that is, 10 47 feet above sea-level. The discharge is 17·6 gallons a minute, but the tube is filled with sand for more than 3 feet from the bottom, which when cleared may allow of an increased flow.

A block of wood or a tree trunk was met with embedded in the sand at 72 feet, which disappeared, however, in some unaccountable manner after being cut at with the jumper for two or three days. Mr. Poulain seems to think that it may have been carried off by the current of water at this horizon; but such freedom of motion is hardly conceivable in alluvial strata;[1] the trunk has been probably just shoved aside.

The beds traversed are:—

| | Feet. |
|---|---|
| Vegetable mould | 1·96 |
| Sandy soil | 31 65 |
| Black clay | 7·87 |
| Coarse and fine sand | 39 36 |

This succession would tie in well with the sections exposed by the Savana, Jardin d'Acclimatation, and Upallem borings, though the clay band has thinned out a good deal from what it is at the Savana well

Another well was commenced last year in the village of Archiwakum, about 7 miles south of Pondicherry, which reached a depth of 144·32 feet, after passing through the following strata.—

| | Feet. |
|---|---|
| Vegetable mould | 1·64 |
| Red sandy soil | 13 12 |
| Micaceous sand | 13 12 |
| Very hard clay of yellowish colour, streaked with veins of light green clay, with some layers of white sand | 111 52 |
| "A sort of Molasse" of reddish yellow colour | 3 28 |
| Sand[2] | |

The water ascended from the later deposit to within 6·56 feet of the surface soil, the wells of the neighbourhood having their water at 13·77 feet below surface, or perhaps about sea level.

This boring is stopped for the present, as the pipe cannot be forced down any further; but a second pipe is to be inserted in this, after which better progress may be made.

The boring in Mr. Cornot's compound, which was noticed in my previous paper (*l. c.* p. 115), has been again continued with the hope of finding a sheet of better water. It is, I believe, nearer the sea than any of the other wells to the south, and a certain oscillation of the hydrostatic level of that sheet was observed

[1] Free and cavernous passages are, I fancy, only possible in hard and rocky strata, and most frequently in soluble rocks, such as limestones.

to be apparently in accord with the rise and fall of the tide; but I have received no further information on this point As bearing on this an important fact was brought to my notice by His Grace the Duke of Buckingham in connection with the tidal observations made at Madras by Colonel Baird, which shows that there is very free percolation of fresh water into the sea on the coast there. It appears that a well or cylinder was sunk in the vicinity of the harbour works for a tidal gauge, and it was found that the water in this well became fresh in a very short space of time. This indicates a head and large supply of water which should be struck by borings of no great depth. It may be that a stratum of this kind has been tapped by all the wells, except that of the Ville Noire and in the neighbourhood of Pondicherry, the few tubes put down having offered a freer exit than that existing, not only on the sea face, but also in the beds of the rivers near the coast.

This observation at Madras implies that the flow of water shows itself at a very shallow depth, but the free percolation must be deeper than this under the Madras plain, for it is well known that at the ordinary depth to which open wells are made here, there is not free communication of their waters. For instance, in many compounds, wells have been dug at various spots, only some of which contain fresh waters. A case in point is that of Mr. Franck's compound on the Mount Road, an area of about 3 or 4 acres in which, as far as I remember, 5 wells were dug, most of which gave brackish water, so here in this small space and at a very shallow depth, are seams of permeable strata which can hardly be in free communication with each other.

## SALT IN RAJPUTANA, *by* C. A. HACKET, *Geological Survey of India.*

The soil of Rajputana, over wide areas, is impregnated with salt. This is more particularly the case on the western side of the Arvali range of hills, where large quantities of salt are manufactured from the efflorescence developed on the surface, and the water in the majority of the wells is too brackish to drink, and in some places the only drinking water obtainable is from small tanks in which the rain water is collected.

The country on the eastern side of the range, north of Ajmere, is also frequently saliferous, but with the exception of a few places, like Sámbhar and Bhartpur, not nearly to so great an extent as on the western side. South of Ajmere, on the eastern side of the range, salt is not met with in any quantity.

So many descriptions of the sources and process of manufacture of the salt of Rajputana have been published, of which the most complete are those in the Gazetteer of Rajputana and the Reports on the Administration of the Inland Customs Department, that it is unnecessary for me to enter into these particulars. The object of this paper is to give a brief description of the rocks in the neighbourhood of these salt sources with reference to the possible origin of the salt.

The salt is obtained from four sources—

*1st.*—From the large shallow lakes, from which great quantities of the best quality of salt are obtained.

*2nd.*—From earth-works, or the collection of the efflorescence on the surface of the soil, re-dissolving it in pits, and allowing it to evaporate in shallow pans.

*3rd.*—From weak brine wells, as at Bhartpur.

*4th.*—From the deposits formed in old beds of rivers.

The earth-works used to be exceedingly numerous, particularly on the western side of the Arvalis, but they are now mostly abandoned. Large quantities of salt were also obtained at Pachbadra, from pits sunk in a hollow supposed to be an old bed in the Lúni river.

Under the new salt revenue regulations the works at Bhartpur are closed, but they were once extensive. In the Gazetteer of the Bhartpur State, salt figures as more than two and a half lakhs of rupees in the revenue receipts for 1873-74. The principal works were close to the west of the city, where large evaporating areas were supplied with brine drawn from wells in the open plain. The nature of the source is altogether obscure: there is no natural surface efflorescence or any other sign to indicate the salt below: rich cultivation is carried on close to the brine wells, and in other wells at a short distance off sweet water stands at about the same level. At the time of observation (December 1865) the briny water was only 20 feet from the surface, and was said to be 20 to 30 feet deep. A well then being worked was said to have been in use for 28 years, without sensible change in the quality of the water. In one unlined well the 20 feet over water level was seen to be one unbroken mass of sandy kankary clay, of the type so general in the great alluvial deposits of the plains.

At present the manufacturing operations are almost restricted to the salt lakes, the most important of which are—

Sámbhar on the borders of Jeypore and Jodhpore—

| | |
|---|---|
| Kachor-Rewasa ... ... ... ... | in Shaikhawáti. |
| Didwána and Phalodi ... ... ... .. | in Jodhpore. |
| Lonkára Sur ... ... ... ... | in Bikaneer. |

But as I have visited only the first three of these lakes, my remarks will be confined to them.

*The Sámbhar Lake*—is situated on the eastern side of the Arvali range (Indian Atlas sheet 33, S. E.). Its greatest length is about 20 miles, and the average breadth is about 5 miles. Its greatest depth, near the centre, at the end of the rains, is seldom more than 3 feet.

The Arvali range near the lake consists of several broken parallel ridges of quartzite, some of them rising to a height of 1,000 feet above the level of the plain. The ground between the ridges is not much higher than the level of the plain to the east, and is mostly covered by the blown sand.

The country east of the range, and surrounding the lake, is covered by long ridges of sand running in an east and west direction, some of them upwards

of 100 feet in height above the level of the lake; thus the northern shore of the lake near Gudha is 1,184 feet above sea level, whilst An, about 1 mile from the southern shore, is 1,262 feet, Singla, 4 miles from the southern shore, 1,292 feet, and Duri, about 6 miles east of the lake, 1,363 feet above sea level.

These ridges of sand are formed by the west wind bringing the sand through the gaps in the ridges of quartzite forming the range. The lake is merely a hollow in the sand, lower than the surrounding country, from the fact of its lying under the lee of one of these high ridges and so protected from the blown sand.

The drainage area of the lake is about 2,200 square miles.

Of the two principal streams that flow into the lake, one takes its rise about 50 miles to the north-east, and the other near Ajmere about 40 miles to the south.

As the lake becomes dry, a deposit of black mud is left at the bottom, which, when dry, contains numerous small crystals of salt. Mr. Adams, the Assistant Commissioner of Inland Customs at Sámbhar, gives the following section of a pit sunk 10 feet deep in the bottom of the lake near the low water level opposite Japog. "After penetrating through a layer of about one and a half feet in thickness of the dark greyish sand which, when covered with water, becomes the black mud of the lake, about half a foot of quicksand with brine was met with. Below this a black micaceous sand occurred, which was much decomposed on the surface, but which became gradually harder downwards. A very similar stratum of micaceous schists[1] occurs in wells about 4 miles to the south-east of Japog." (Inland Customs Report, 1870-71, p. 113).

Outcrops of these schists occur on the shores of the lake near Japog and several other places. They belong to the Arvali series of rocks, of which mention will presently be made.

Calcareous deposits of considerable thickness are of frequent occurrence round the shores of the lake. They are well developed near Sámbhar and Nanwa. These deposits are apparently formed by the infiltration of water into the blown sand forming the banks of the lake. Upwards of 20 feet of this concretionary limestone is exposed in a well sunk on the southern shore of the lake near Kotarsina.

The following statements relating to the specific gravity of the lake water is taken from Mr. Adams' report for 1870-71 (*l. c.* p. 115) :—"The specific gravity of the lake water during the past rains never was less than that of sea water, the specific gravity of sea water being given as 1·03, while the lake water on 30th July gave 1·03. In August about 5 inches of rain fell, and as the evaporation, owing to the humid state of the atmosphere, was slight, the specific gravity was the same as that at the end of July. During September the specific gravity kept at 1·04; in October it increased from 1·05 to 1·07; in November it varied from 1·08 to 1·10; in December, owing to some slight showers of rain, it was reduced to 1·095; in January it increased from 1·11 to 1·14; in February it increased from 1·15 to 1·20, and at this specific gravity salt began to deposit. No difference of gravity was at any time observed in the brine taken from the surface and that taken from the deepest part of the lake.

[1] It is to be presumed that the 'sand' of the preceding sentence is decomposed schist.

"The specific gravity of a saturated solution of salt is 1·2046, but on the 9th March the specific gravity of the highly concentrated lake brine was 1·22, and on the 30th March 1·215. In this state the chemical solution is so dense that precipitation in the form of truncated pyramid-shaped crystals (the well-known form of the Sámbhar salt) is constantly occurring, until a layer of salt about 2 inches in thickness overlies the mud of the lake."

Dr. H. Warth gives the following analyses of the lake brine (*l. c.*, 1871-72, p 155):—

"The samples examined were as follows:—

1. Lake brine—
   - A.—Common brine from the lake, 10th December, 100 yards from the shore near Japog.
   - B.—The same brine artificially saturated.
   - C.—Brine from Japog, 24th January.
2. Subterranean brine, or percolation brine, taken from diggings in the lake bed at places where the surface water had receded—
   - A.—Brine from reservoir in walled enclosure No. 2, 10th December.
   - B.—Brine from the same, on 13th January.
   - C.—Brine from a hole made on the shore near Japog, 10th December.
3. Mother-liquor—Residue brine from the manufacture of salt in *kyaris*—
   - A.—Mother-liquor from walled enclosure, No. 2, December 1869.
   - B —Mother-liquor from the same, 17th January 1870.
   - C —Mother-liquor from walled enclosure No. 1, 26th January 1870.

*Analyses.*

| | Lake Brine | | | Subterranean Brine. | | | Mother-Liquor. | | |
|---|---|---|---|---|---|---|---|---|---|
| | A. | B. | C. | A. | B. | C. | A. | B. | C. |
| Dry residuum .. | 21·9 | 27·1 | 27 8 | 22 7 | 20·8 | 20·1 | 30·6 | 30·4 | 30 4 |
| Water ... ... | 78 0 | 72·6 | 72 2 | 77·5 | 79·3 | 80 0 | 68·8 | 68·8 | 68·4 |
| Chloride of sodium .. | 19·9 | 24 6 | 24 8 | 19·7 | 17·5 | 17·3 | 19·1 | 20·5 | 19·4 |
| Sulphate of soda ... | 1·6 | 2·0 | 2·6 | 2·5 | 2·5 | 2·5 | 7 1 | 9·4 | 6 5 |
| Carbonate of soda .. | 0·4 | 0 5 | 0·4 | 0·5 | 0·8 | 0·3 | 4·4 | 0·5 | 4·5 |
| TOTAL ... | 99·9 | 99·7 | 100·0 | 100·2 | 100·1 | 100·1 | 99·4 | 99·2 | 98·8 |
| Percentage of foreign salt, in dry residuum ... | 9·1 | 9·2 | 10·8 | 13·2 | 15·9 | 13·9 | 37·6 | 32·6 | 36·2 |
| Average ... ... | 9·7 | | | 14·3 | | | 35·5 | | |

*Analysis of clay from Lake-bed.*—"The sample was taken from the Lake-bed, some feet under the surface, when the reservoir was being excavated, in walled enclosure No. 2, in December 1869

| | |
|---|---|
| Water | 38·9 |
| Silica | 25·0 |
| Oxide of alumina, iron, &c | 8·6 |
| Carbonate of lime | 8·1 |
| ,, of magnesia | 3·4 |
| Chloride of sodium | 13·1 |
| Sulphate of soda | 2·6 |
| Carbonate of soda | 0·3 |
| TOTAL | 100 |

"Proportion of foreign salts in the soluble substance, 18·1 per cent."

*The Didwána salt lake*—is situated about 20 miles to the west of the Arvali range and 35 miles from the Sámbhar lake in a north-westerly direction. It is about 4 miles long and 1½ miles broad. During the rains there is mostly a foot or so of water in the lake, but which soon dries up. When I was there in November it was quite dry, with the exception of a few patches of mud.

The origin of the lake is similar to that of the Sámbhar lake. It is situated under the lee of a short ridge, between 300 and 400 feet in height above the level of the plain, and so protected from the blown sand, which about here forms long ridges sometimes upwards of a 100 feet high, extending in an east-north-east direction. This is also the direction of the longer axis of the lake.

Two dams are built across the lake at about three-fourths of a mile from either end, to cut off the access of surface water.

The mode of procuring the salt differs from that at the Sámbhar lake. At Didwána wells of about 6 feet in diameter are sunk in the bottom of the lake to a depth of about 15 feet, the bottom of the well is then pierced to a further depth of 2 or 3 feet, by a heavy iron-shod pole, when the brine rises suddenly to within 4 feet of the mouth of the well, at which level it constantly stands during the hot weather and the rains. When the wells are first pierced large quantities of sulphuretted hydrogen gas are evolved, and even in the old wells the smell of the gas is very strong.

The sections exposed in the wells consist of alternations of sand, and sandy calcareous tufa.

The brine from these wells has a specific gravity of about 1·2. It is lifted by the *chanat*, or lever bucket, into shallow pans of about 20 yards square and allowed to evaporate, when the salt is collected.

The manager of the works told me that the cost of manufacture was only Re. 1 for 200 maunds.

*The Kachor-Rewassa lake*—is situated in Shaikhawáti, about 30 miles north of the Sámbhar lake. It is very shallow, and when I was there, perfectly dry, and no manufacture of salt was being carried on.

*Geological features.*—The rocks forming the Arvali range belong to the gneissic or metamorphic series and the lower transition or sub-metamorphic series. The latter series consists of schists, slates, limestones, and quartzites, and has been called the Arvali series. All the sections across the range show that the rocks have been greatly disturbed, folded, and repeated several times. The dip is always high, seldom less than 70°, and often vertical. The most prominent features in the range are formed by the quartzites, the highest member of the Arvali series; thus, Táragarh hill near Ajmere, 2,855 feet above sea level, is formed of this quartzite, as well as the ridges immediately west of the Sámbhar lake, one of which rises to the height of 2,430 feet, and the ridges of quartzite, of the southern portion of the range, south of Todgarh, attain an elevation of upwards of 4,000 feet above the sea.

Complete sections of the Arvali series, from the gneiss to the top quartzites, are exposed both to the south, near Ajmere, and to the north of the Sámbhar lake in Shaikhawáti, but in the neighbourhood of the lake only a skeleton of the range is left, consisting almost entirely of vertical ridges of quartzite, the lower and softer slates, schists, &c., having for the most part been worn down below the level of the plain and covered by the alluvium and blown sand.

Several outcrops of the Arvali schists occur on the shores of the Sámbhar lake, particularly a few miles west of Sámbhar. The only other rocks exposed are portions of two broken, roughly parallel ridges of quartzite, one at the western end of the lake, and the other near the centre, a short distance east of Nanwa. The famous marble quarries of Makrána are situated on the western side of the range, about 10 miles due west of the lake.

No rocks are exposed in the bed of the Didwána lake, but a considerable thickness of slates occurs in the hills a short distance to the west; there are also some hills of quartzite at Kolia and Patan, a few miles distant from the lake.

Besides the metamorphic and sub-metamorphic rocks of which the central range is composed, another series of rocks, the Vindhyans, occur near it on the western side. The eastern boundary of these Vindhyans runs from Sojat to Khátu, at a distance of about 20 miles from the western edge of the range. West from this line they extend almost continuously to the west of Jodhpore. The Vindhyans of this area consist of sandstone, limestone, and conglomerate; they are but slightly disturbed, being mostly horizontal, and seldom dip at a higher angle than 5°. They rest quite unconformably upon the Arvali series. Good sections of this unconformity are exposed both at Sojat and Khátu, where the nearly horizontal sandstone of the Vindhyans rests upon the edges of the vertical Arvali slates.

As no fossils have as yet been found either in the Vindhyan or Arvali series, their age cannot be determined with any certainty. There is a great break between the Vindhyans and the Gondwánas, the next series in ascending order; and as the lowest group, the Tálchirs, of the latter are probably permian, the Vindhyans are not likely to be younger than the carboniferous and possibly much older. The unconformity between the Vindhyans and the Arvalis is very great, it is almost necessary to suppose that the Arvali range was formed previous to

the deposition of the Vindhyans, in which case the Arvali series would be of very ancient date, probably cambrian.

The favourite theory to account for the origin of the salt in Rajputana is, that the rocks of the Arvalis belong to the "Permian system," which is confounded with the saliferous rocks of England; and that the salt of this region is derived from some of these beds as yet undiscovered, being dissolved by the rains and rivers and redeposited in the shallow lakes.

I have already shown that both the Vindhyans and Arvalis are older than the permian; but this would not dispose of the assumption that either one or both of these series might contain salt beds. As the lower beds of the Arvali series are covered by the alluvium and blown sand in the neighbourhood of the Sámbhar and Didwána lakes, it is impossible to say that salt beds do not exist in that position; but it is evident, from the wide distribution of the salt, that it could not be derived and distributed in the alluvium from one or two local sources, and therefore, if the origin of the salt be in the rock, its occurrence there must be frequent, and the probabilities of detecting it (or traces of it) *in situ* would be very great.

I have examined a very large area occupied by the Arvali series, from the extreme northern end of the Arvali range to within a short distance of Mt. Abu, without finding any trace of a salt deposit, notwithstanding the numerous complete sections of the series that are exposed, from the gneiss to the highest known beds.

There seems even less probability of salt escaping detection in the Vindhyans; for in the very large area covered by them in this region, both to the south-east and to the north-west of the Arvali range, the whole formation is exposed, from its very base, without any contortions to favour the concealment of peculiar beds, yet no trace of a salt deposit has been observed.

The artificial lakes, wells, and rivers afford stronger evidence that the salt is not derived from either the Arvalis or the Vindhyans. There are several large artificial lakes and tanks within the range at elevations greater than that of the plains. The principal of these are the Ana Ságar at Ajmere, situated in an eroded anticlinal fold of the Arvali strata in the centre of the range, Pohkar lake near the western side, and the Rae Samand at Kankroli on the eastern side of the range. The water supplying these as well as the numerous smaller tanks of the range flows over more or less complete sections of the Arvali rocks, and is in all of them sweet.

Of the numerous wells sunk in the Arvali rocks of the range, I do not remember that the water in any of them was brackish.

The Luni river, and its numerous tributaries draining the greater portion and a long length of the Arvali range, contain sweet water as far as the western edge of the range; but after flowing some distance over the plain to the west, the water becomes saline, and salt is deposited on the banks in the hot season, when the rivers cease to flow. At Pachbadra, 35 miles south-west of Jodhpore, large quantities of salt are manufactured in a valley near to, and probably an old bed of, the Luni. The Banas river and its tributaries flowing to the

east, drain a considerable portion of the range, and the waters remain sweet throughout

The wells sunk in the Vindhyan rocks, on the western side of the range, contain, without exception, sweet water, while those sunk in the alluvium a short distance off contain brackish water.

As it seems improbable that the salt is derived from either the Arvali or the Vindhyan series, the only visible source remaining is the alluvium. It has been suggested that the alluvium is, in part at least, of marine origin, and that the salt lakes are parts of the old sea bottom in which the salt has accumulated. As no good sections of the alluvium west of the Arvali range are exposed, the beds of all rivers being shallow, seldom more than 20 feet below the level of the plain, and as large areas, more especially in the northern portion, are covered by blown sand, it is difficult to produce any direct evidence on this point.

Mr. Blanford found a mollusk (*Potamides layardi*), an inhabitant of salt lagoons on the coast, in one of the salt pools near Umerkot, from which he inferred that an arm of the sea extended as far as this in recent times. But Umerkot is more than 300 miles nearer the sea and several hundred feet lower than the level of the plain near the Sámbhar lake In the portion of the alluvium that I have examined, extending south to 25° north latitude, I have not seen a marine shell; but in several places, in the old banks of the rivers, I have found fresh-water shells of existing species.

In my examination of the alluvium west of the Arvali range, I met with several ridges, many miles in length, of water-worn boulders, often as much as 1 foot in diameter. Nearly all of them were formed of the hard quartzite of the Arvali series, and must have undergone much rolling to reduce them to their present shape. A short distance west of Khátu, and about 35 miles west of the Arvali range, there are two parallel ridges formed of these boulders, about a mile apart at their nearest points and about 6 miles in length, running nearly north and south. How far north they may extend I am unable to say; but to the south they reach in a broken line to the Luni river, a distance of upwards of 70 miles. The boulders sometimes rest upon the Vindhyans, and are frequently isolated in the alluvium. The base of the ridges is never above the level of the plain. The boulders are clearly superficial to the Vindhyans and of comparatively recent origin; but whether they mark the course of a large river or of an ancient coast line, it would be rash at present to decide.

*General conclusions.*—If the question of origin from rocks underlying the alluvium could be decided from all that is visible of these rocks above the alluvium, and if the whole nature of these covering deposits could be told from what we can see of them in shallow sections at the surface, the answer in both cases would be in the negative, and the only source remaining for the salt would be its local production from natural causes still in operation. Theoretically the case is possible, as any modern schoolboy knows that lakes without an outflow, and to a great extent the ocean itself, become saline from the continual concentration by evaporation of what we call sweet water. In the present case, however, the process with known data seems inadequate to the result. For a long time the

production of salt from the Sámbhar lake has been on an extensive scale, and, as a source of salt, the lake dates from the mythical age. Myths are, no doubt, still a popular product of contemporary invention, and I cannot say whether historical documents throw any light upon the remote statistics of salt manufacture at Sámbhar. But the facts in hand are sufficient, without appealing to ancient history; and I have seen no mention of any symptoms of failing in the supply. To accomplish so much within any reasonable time, with a catchment basin of only 2,000 square miles, would seem an impossible feat, and we must not forget that the formation of the lake itself, as already described, is apparently due to conditions that are, at least geologically, modern; the reign of sand in Rajputana may almost certainly be assigned as a result of the reign of quasi-civilized man, the Rajput and his compeers; for it can scarcely be doubted that it was once in the possession of the forest primeval.

In this connection it has been considered whether we might not call in the aid of some of the great northern rivers. It is well known that the Satlej formerly flowed far to the east of its present course, and it is geologically possible, or even probable, that the Jumna once upon a time flowed through Rajputana, west of the Arvali range.[1] The waste waters of those rivers, distributed widely by overflow and percolation, before the channels became diverted into lower ground, must have supplied to the soil a very large amount of saline matter, and under suitable conditions of evaporation and percolation this might be retained in those upper deposits At the present day all the rainfall on the tract between the Jumna and the Satlej, where is now the 'divide' between the basins of the Indus and the Ganges, including the water of some considerable streams from the Siwalik hills, is wholly dissipated or absorbed within that area, there being little or no escape by surface drainage. It seems, however, that this aid cannot be called in at Sámbhar, without almost inadmissible assumptions as to changes of level. There is certainly no room to suppose that the area under consideration has suffered from erosion; and at present the alluvial spill from the Himalaya on the north meets that of the Arvali from the south about Hissar, where we find the lowest ground in the cross-section of the Indo-Gangetic plains at their watershed. The elevation at Hissar is 700 feet, or nearly 500 feet lower than the Sámbhar lake, 160 miles to the south.

There is yet another fact to be considered in this discussion. Without exception, so far as known, sweet water is obtainable from the alluvial deposits at lower levels than the saline water. I cannot say that this has been tried at any actual focus of salt production, but it is a fact of universal experience and practice in the region under notice and throughout the plains of north-west India to sink deep wells for fresh water, where the upper water stratum, as very often happens, is too salty for use. It might seem at first sight that this fact would at once put out of court a question we have had to leave undecided—whether there may not be recent marine deposits below the surface alluvium, which latter is everywhere proved by its fossil contents to be of fresh water origin; but it is abundantly proved that strata which must have been originally impregnated with

[1] *See* section, 'The Plains,' in the Gazetteer of the Punjab.

salt water become purged by the forced circulation of fresh-water underground from artesian pressure, so our fact is of small account in the argument for or against marine strata in the alluvium. It is, however, of great weight in the argument for the local and actually operative production of these deposits of salt; for it is almost beyond question that, as a common phenomenon in Upper India, the saline condition of the upper water stratum is due to the present operation of assignable conditions upon the surface and subsoil waters, whether rain water or as derived by percolation or irrigation from rivers and canals.

With such good evidence of a *vera causa* of salt production actually in operation, it should certainly be an object of continued observation and study whether such extreme cases of local concentration may not be brought within its action. It may, nevertheless, be well to point out what alternatives remain for those extreme cases. We can, I think, confidently assert that the Arvali formation (or rock series) is not the repository of rock-salt. These strata occur in many outliers far into the alluvium on the prolongation of the range, and always in the same condition of extreme disturbance. There is a strong probability that what is seen of them in natural outcrops throughout the range may be taken as fully representative of the whole series. Of the Vindhyans it may be asserted with even greater certitude that, so far as seen, they do not and never did contain rock-salt. It has even been conjectured that this formation, so far as known, is of fresh-water or subaerial origin; but this very conjecture might encourage the supposition of contemporary salt deposition in contiguous areas; while the undisturbed condition of these rocks would be in favour of the total concealment of any such deposits at a lower level than the actual outcrops. The area of covered ground here is quite extensive enough to conceal any such deposits of Vindhyan or of any subsequent age; and thus there remains the possibility of such a source for the salt of Sámbhar and of other localities of apparently unlimited production.

## Record of gas and mud eruptions on the Arakan Coast on 12th March 1879 and in June 1843.

The following reports by the local officers upon cases of eruptive action on the Arakan Coast are in continuation of those published in the Records for February 1879, Vol. XII, p. 70 :—

From Lieut.-Colonel W. W. Pemberton, Deputy Commissioner, Kyouk-Phyoo, to the Commissioner of Arakan, Akyab,—No. 41-14, dated 23rd June 1879.

Referring to your endorsement No. 451-222, General, dated 7th May last, on the subject of a recent volcanic eruption, I have the honour to state as follows :—

The Extra Assistant Commissioner of Cheduba was asked for a report on the subject, and in his reply he states that the eruption did not occur on the island of Cheduba. Some ermen, who were out at sea-fishing at the time of the occurrence, told him that they had

observed the phenomenon and thought it occurred on the island of Ma-Gyee, while person residing on that island said they had seen the illumination seawards north of the island. The Extra Assistant Commissioner then states that afterwards he was informed by a Burmese medical practitioner who happened to be at Sandoway on the night of the occurrence, that the explosion took place on a small island situated south of the Tha-dai-chyoungwa creek, in the Sandoway district, which statement was corroborated by some fishermen who came from Kha-Mongdoon, in the Sandoway district, and who happened to be fishing at sea at the time the phenomenon occurred.

Previous to the receipt of your letter under reply, I had heard of the occurrence, and sent to the Extra Assistant Commissioner of Cheduba for a report on the subject, but the outbreak of cholera in the town prevented him from making the enquiry for some time.

From MAJOR M. C. POOLE, Deputy Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,—No 3-49, dated 29th April 1879.

In continuation with the subject of your letter No 95, dated 4th instant, I have the honour to mention that when at Htsengoung on the 12th March, I saw the sky brilliantly illuminated by an eruption of the volcano at Cheduba. Some of the Burmans with me going on shore and looking across the sea in the direction of Cheduba distinctly saw the flames. You have doubtless received further details from the Deputy Commissioner, Kyouk-Phyoo.

FROM MAJOR M. C. POOLE, Officiating Deputy Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,– No. 3-90, dated Sandoway, 31st July 1879.

In continuation of the subject contained in my letter No. 3-49, dated 29th April 1879, I have the honour to furnish all the additional information I have been enabled to collect regarding the volcanic phenomenon observed on the 12th March last. To my observation it appeared to emanate from some island lying north-west of Htsengoung; but not taking the bearings of the distant flames, I am unable to accurately define their position and joined in the hasty but not unnatural conclusion of the other spectators, that it was in the direction of the island, of Cheduba. I visited the village of Ka moun-doon on the 22nd instant, and there held conversation with some who had seen it; the day was beautifully clear, and from the slightly elevated shore, the southern extremity of the island of Ramree, the islands of Zagoo, Magree Kyoon, and Yey Kyoon, all stood out clear and distinct like a chart; in the distance could be distinguished the sharp serrated outline of hills in the island of Cheduba. The head-man of the village pointed out to me two sharp pinnacle-shaped rocks far out on the horizon, and known by the name of Kyouktabon which he said he was certain was the exact spot where the flames came from. These rocks lie south of Cheduba, and when viewed from Htsengoung, in a line with the north of that island and Yey Kyoon. This latter island was the scene of a similar occurrence in 1843, Captain Hopkinson's account of which I send a copy of. I am inclined to believe that most of these rocks and islands contain cavernous hollows in which petroleum or other gases are generated, and that they occasionally ignite and burst out. Several men who were at sea that night gave me different versions of what the aspect of the phenomenon was to them, varied of course by the different positions from which they saw it; I am of opinion, however, that the testimony of the headman at Ka-moun-doon is the most trustworthy, and my own opinion inclines to an endorsement of his view.

FROM CAPTAIN H. HOPKINSON, Officiating Senior Assistant Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,—dated 25th November 1843.

Having, in compliance with the instructions contained in your letter to my address No. 838 of the 21st ultimo, proceeded to Rekeorg or Flat Island for the purpose of making enquiries into the volcanic eruption which has recently been observed at the southern extremity of that island, I now beg to submit to you the result of my enquiries with all the information I have been able to collect in the matter.

2. Before I give the substance of the Thoogyee's deposition, I will endeavour to state what I saw myself, premising shortly that whatever island may have been formed by the submarine volcano has either sunk or perhaps, being merely composed of mud and loose volcanic fragments, has been washed away during the south-west monsoon, leaving no trace of its existence, and not even having disturbed the reef of rocks among which it is said to have arisen. I lament exceedingly my total ignorance of geological science which would most probably have led me to pass over much which was really valuable whilst I noted down objects of trivial importance, and which also prevents me from communicating any useful observation I might have made in such language as would be understood by a scientific person.

3. I arrived at Rugyoung on the third day after my departure from Sandoway, and immediately put myself in communication with the Thoogyee of the place, whose attendance to depose what he knew about the volcanic eruption and also to act as my guide to the site of their occurrence I procured for the following day. We started early in the morning and arrived near the small island in the vicinity of which the eruptions were remarked at 8 P.M. I was obliged to proceed for upwards of a mile from the island itself in the jolly-boat; reefs of sunken rocks running out in every direction preventing a nearer approach for the schooner, though otherwise the water was of a considerable depth, being from two to three fathoms within a boat's length of the little island itself. My office has not been furnished with a general chart of the province, and I do not know whether the island has been noted or not, but it may be easily identified, as I was careful to take its exact bearings to known points on the coast. I also made a rough survey of it by circumferenter and enclose a sketch thereof, showing the bearings, site of volcanic eruption, &c., &c. The rocks which formed the basis of the island were chiefly the common sandstone of Arakan, interspersed with large masses of rock, of which No. 1 of the specimens I had the honour to forward in the *Swallow* is a fragment. I could obtain no distinct traces of stratification on any part of the island, the action of the sea having broken up its surface into a confused mass of rocks. I have marked on the map the site of the volcanic eruption as given by the Soogree, but further than the mere direction goes, I do not think much dependence can be placed on its accuracy. The Soogree never visited the volcanic island; the eruption occurred during the height of the rains, when it is seldom clear for even a few hours, and the Soogree's nearest point of observation was, I should say, at least 4 miles distant. I should infer that the eruption must have been on a small scale, since from the testimony of the natives it appears that none of the numerous rocks near which they were observed have been altered in position, neither cast down nor upraised. I have marked on the sketch the situations from whence I took the different specimens before alluded to; the trap rock which I labelled hornblende was broken off a large rock about 12 feet square at top. The piece I have called felspar was from an adjacent rock, but smaller. I could only find the iron pyrites on the side nearest the volcano; there it was most plentiful, and I might have collected it by the maund; one specimen which I have called quartz is, I believe, limestone; its appearance at first misled me. On the sand mound I found large quantities of sponge of different kinds. I saw no coral on the island, nor any formation of it among the rocks, an unusual circumstance in Arakan. I looked for pumice, but did not find any.

4. The above is all that occurs to me to remark upon, and I shall now proceed to give the substance of the information gained from the Soogree he states that in the month of Wageo or June, at about 8 o'clock in the morning, he observed the eruption for the first time, issuing apparently from between three rocks to the eastward of hi village and about one hour's sail distance from it, to the south of Thee-byoo-gyoung-let, White Sand Island, the one in the sketch. The eruption was like fire of a bright red colour, and continued without intermission for three days, when it ceased, and deponent then observed that a small island has arisen from the sea; this island lasted for about a month, but he cannot say when it actually disappeared, for the weather was very boisterous during the whole time, and it was only by a calm supervening and the waves subsiding that he found the island had ceased to exist. The surface of the sea was as before, and not a rock was displaced; deponent did not visit the volcanic island, nor did any one in his circle, the fury of the waves prevented all approach to it. When he first visited the island nearest the site of the eruption, the only change he noticed was that some cocoanut trees had disappeared -probably been washed away—which were planted there about two years ago. During the time the eruption continued there was an unaccountable increase of water in the wells and tanks of his village; he also felt several slight shocks as of an earthquake during the time. The above, meagre as it is, is all the information I could obtain from the Soogree, but it was fully confirmed by the different inhabitants of Rekcoung whom I questioned on the subject.

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ADAMS, A. LEITH.—On the Recent and Extinct Irish Mammals (1878), 8vo, Dublin.

BALL, V.—Jungle Life in India (1880), 8vo, London.

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BALTZER, DR. A.—Der Glärnische (1873), 4to, Zurich.

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Ditto Ditto Pottery, Glass and Silicates, Furniture, 2nd Edition (1877), 8vo. London

Ditto Ditto Metallic Mining and Collieries, Coal, Building Stones, Explosive Compounds, 2nd Edition (1878), 8vo, London.

Bronn's Klassen und Ordnungen des Thier-Reichs. Band VI, Abth. III, Reptilien, Lief. 2-4, and 5-7; Band VI. Abth. V, Mammalia, Lief. 23-25 (1879), 8vo, Leipzig.

CHURCH, JOHN A.—The Comstock Lode, its Formation and History (1879), 4to, New York.

CUNNINGHAM, ALEX.—Ladak, Physical, Statistical, and Historical (1854), 8vo, London.

DAUBRÉE, A.—Études Synthétiques de Géologie Expérimentale (1879), 8vo, Paris.

DOYLE, P. Petroleum and its Distillate Kerosine (1880), 8vo, Brisbane.

THE AUTHOR.

DUFRÉNOY ET ÉLIE DE BEAUMONT.—Explication de la Carte Géologique de la France, Vols. I (1841), II (1848), III, pt. 1 (1873), and IV, pt. 2 (1879), Text only, 4to, Paris.

FLOWER, WM. HENRY.—Catalogue of the Specimens illustrating the Osteology and Dentition of Vertebrated Animals, Recent and Extinct, contained in the Museum of the Royal College of Surgeons of England, Part I, Man (1879), 8vo, London.

FRITSCH, DR. ANT.—Fauna der Gaskohle und der Kalksteine der Permformation Böhmens Band I, heft 1 (1879), 4to, Prag.

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*July 12th. 1880.*

# RECORDS

OF THE

# GEOLOGICAL SURVEY OF INDIA.

**Part 4.]** **1880.** **[November.**


## ON SOME PLEISTOCENE DEPOSITS OF THE NORTHERN PUNJAB, AND THE EVIDENCE THEY AFFORD OF AN EXTREME CLIMATE DURING A PORTION OF THAT PERIOD, *by* W. THEOBALD, *Geological Survey of India.*

The deposits to which I propose to direct attention in the following notes are those commonly called 'recent deposits,' and as such commonly neglected, though, if patiently interrogated, they are capable of affording a key to the solution of some interesting questions bearing on mundane physics of no very remote age. I allude, of course, to the much-vexed question of the extension, universal or otherwise, of glacial phenomena during a 'great ice age,' and particularly of the proofs, *pro* or *con*, for the existence of any such glacial phenomena in or near the plains of India, or at so low a level in the Northern Punjab as 2,000 or thereabouts. So long ago as 1867, Dr. Verchere recorded the presence of 'erratic' blocks in the Potwar at less than 2,000 feet altitude (Jour., As. Soc., Bengal, Vol. XXXVI, Part II, p. 113); but from the known liability of the Indus valley to cataclysmal inundations, consequent on the bursting of dams in its upper portion, the true bearings of these masses have never been properly appreciated, nor has any attempt been made to study the facts in detail or interpret the relation they bear to the general geological history of the district, and to postulate the conclusions we may legitimately deduce therefrom. The following papers may be beneficially consulted as bearing on the matters in question, and I cannot better preface my present remarks than by briefly reviewing what has been already written on the subject, and pointing out which statements require modifying, and wherein I differ from, or coincide with, the opinions of the writers I quote below—

**Wynne, Records, Vol. X, pp. 107, 112, 122.**
**Theobald „ „ X, p. 140.**
**„ „ „ X, p. 223.**
**Wynne, Memoirs, „ XIV, p. 116.**
**Lydekker, Records, Vol. XII, p. 29.**
**Wynne, „ „ XII, p. 114.**
**Blanford, Manual, pp. lxx, 372, 516, 586.**
**Medlicott, „ p. 668.**

In the first paper Mr. Wynne describes the relations and characters of the post-tertiary and superficial deposits of the North-Western Punjab. These deposits he divides into an upper alluvium (elsewhere termed loëss), largely imbued in places with soda salts, and much cut up by ravines; and a lower division formed of "coarse pebble beds and sand or clay." These beds are described as not only filling the valleys, but covering large tracts of country, as, for example, in the neighbourhood of Ráwalpindi and elsewhere. They are described as rising to 3,000 feet above the sea; but this estimate may be indefinitely extended, if we take into consideration the homologous deposits which were being cotemporaneously formed within the hills, and the high level gravels of the larger river valleys. Mr. Wynne's estimate, however, probably is meant only to include the deposits in the immediate vicinity of the outer hills of the Hazára district. The tertiary period may, in fact, be described as closing in a great subsiding movement of the Himalayan region, whereby the river valleys became filled up to the height of several hundred feet by coarse river deposits, and the whole country overspread by the gravels and the high-level alluvium which rests on them.

One remark of Mr. Wynne I believe to be erroneous. At page 124 we read, "With regard to the existence of a glacial period affecting the upper Punjab in very recent geological times, the only evidence the country seems to offer is in the occurrence of the formerly Indus-borne crystalline fragments at heights of some 2,000 feet above the present bed of the river. These would indicate either a very late elevation of the region traversed by the Indus, or, that when it ran in a channel so much higher, the hilly country to the northward may have been as much more lofty (or even higher still), and regions of perennial snow much nearer than they are at present." The above passage is couched in general terms, but I have reason for knowing that it particularly refers to the Chitapahár range south of Attock, and the word 'fragments,' which might be supposed to refer to 'erratics' really means only the rolled boulders of the Indus gravel. As, however, I felt very sceptical that the Indus, abandoning its deep and rocky gorge to the west of the Chitapahár hills, had ever really flowed here and there over the crest of that range, I addressed enquiries on this point to my colleague, and his reply, though intended, I think, to some extent as confirmatory of such an idea, really supports my own opinion on the subject to the contrary. In his reply, Mr. Wynne says:—"One swallow don't make a summer, one pebble would not make a gravel; *so I can't declare there is any big deposit of Indus gravel on the Chita range*, but all the same there are good large lumps of the Indus boulder deposits scattered about on the ranges of Bágh and Choi, at heights of 2,500 to 3,000 feet, too numerous to have been carried up by humans, *who would not load themselves with two or three seers or more of such stones (gneiss, &c.) and carry them up some thousands of feet for the fun of the thing, or as prisoners do shot drill.*" Now I think these words of my colleague establish the fact that there is no *deposit* of gravel on the Chitapahár range, and that the inference of the former course of the Indus over its height rests on the occurrence of scattered boulders of Indus gravel, and in ignorance of any reason for supposing them to have been transported to the spot in question by human agency.

But a good and sufficient reason does exist for this latter explanation. It is

the habit in all this part of the Indus valley to collect boulders from the vicinity of the river and convey them away on carts or camels for the purpose of strengthening the mud-walls of the houses. Near the river the walls of many houses are mainly built of the larger boulders, whilst at a greater distance, the builders use these stones more sparingly, building them into the corners of the house only, where they protect the mud-walls from injury from passing cattle, &c. In many villages, too, a very old trait of patriarchal times may still be seen. Any very large smooth boulders or stones from Buddhist or other ruins, are brought up into the village, and either ranged under a tree or placed in some convenient spot for the use and delectation of the village headman, and 'grey beards,' precisely as we read in Homer, was the case in Pyle in the days of Neleus, three generations of articulate-speaking men before the fall of Troy. (Hom. Od., Book III, l. 404.)

*Ἦμος δ' ἠριγένεια φάνη ῥοδοδάκτυλος ἠώς*
*Ὤρνυτ' ἄρ' ἐξ εὐνῆφι Γερήνιος ἱππότα Νέστωρ*
*Ἐκ δ' ἐλθὼν κατ' ἄρ' ἕζετ' ἐπὶ ξεστοῖσι λίθοισιν*
*Οἵ οἱ ἔσαν προπάροιθε θυράων ὑψηλάων*
*Λευκοὶ, ἀποστίλβοντες ἀλείφατος οἷς ἔπι μὲν πρίν*
*Νηλεὺς ἵζεσκεν θεόφιν μήστωρ ἀτάλαντος·*
*Ἀλλ' ὁ μὲν ἤδη κηρὶ δαμεὶς Ἀϊδόσδε βεβήκει,*
*Νέστωρ αὖ τότ' ἔφιζε Γερήνιος οὖρος Ἀχαιῶν,*
*Σκῆπτρον ἔχων περὶ δ' υἷες ἀολλέες ἠγερέθοντο·**

An even more probable explanation for the occurrence of Indus gravel at different spots on the Chitapahár range is the popular fashion of ornamenting graves in this part of the Punjab with smooth round stones, those of white quartz and variegated gneiss or schistose rock, being selected more commonly for this purpose. This practice may be noticed many miles from the river Indus, and proves that natural piety is as effective a stimulus for an unproductive expenditure of labour, as the harsh necessity of "shot drill;" and to this latter cause I attribute the presence of the Indus pebbles occasionally met with at considerable height on the Chitapahár hill. In many spots villages formerly existed, which are now abandoned in favour of the plains, owing to the security for life and property which the people now enjoy.

* 'Soon as Aurora, daughter of the Dawn,
With rosy fingers, had unveiled the morn;
From off his couch, Gerenian Nestor rose,
And issuing forth, refreshed by night's repose,
On polished stones, before his palace gate
As Neleus used of yore, the monarch sate.
White, smooth, and glittering in the sun they shone
Unhewn, each block displayed a rustic throne;
But Neleus passing to th' Elysian shade
Wise Nestor reigned and Pyle's sceptre swayed,
Whilst numerous sons around, obeisance made.'

I have myself crossed the Chitapahár range twice, and have both times carefully sought for evidence of the Indus having formerly flowed over it, but without success, and I believe that river has never deviated from the deep gorge whereby it now crosses this barrier. The highest alluvial deposit which can be referred to the river Indus in this quarter, is a homogeneous clay, which is seen in places on the flanks of the range south of Choi,[1] rising to a height (roughly guessed) of between 300 to 400 feet above the present bed of the river.

This clay may possibly be of lacustrine origin if the Chuch Hazára plain and neighbourhood were ever occupied by a lake prior to the lowering of the Indus bed to its present depth. Anyhow I should say 400 feet was the highest level on the Chitapahár range above the present Indus bed, at which any distinct Indus alluvium can be made out. So much for positive indications.

But there is one very powerful negative argument against the idea of the Indus ever having hereabouts flowed at the height indicated by Mr. Wynne.

Above the limits at which the clay in question occurs, the hills are formed of vertical beds of limestone, cut up or furrowed by deep, almost cavernous, fissures, forming a deeply *serrated* surface, which would have acted as the most efficient pebble trap that could be imagined, and into which any pebbles must have been washed, without the possibility of their being subsequently cleared out again. Yet not a single pebble or boulder of any sort can be seen in any of these rifts, the conclusion being therefore irresistible that no wash of gravel has ever taken place over them.

The next papers to notice are two by myself in Records, Vol. X, pages 140 and 223. In the former I describe an alluvial deposit in the Potwar with numerous species of living shells, and a peculiar silt near Jand, possibly indicative of glacial conditions at the time it was being deposited. Perhaps the most important fact, however, was the occurrence of a large 'erratic' "over 20 feet in girth, *resting on alluvium at a high level*, eight and a half miles from Pindigheb and eleven miles from Taman" (l. c., p. 142). This is a valuable indication of the relative age of the glacial conditions presumed to have obtained in the district, and the older alluvium; the instance here quoted not admitting of any doubt as to the fact of the 'erratic' reposing on a thick bed of alluvium. My other paper refers to certain distinctions that should be drawn between 'erratics' of the pleistocene period and the 'erratics,' which in the Salt-range are embedded in strata of mesozoic and palæozoic age, and which are as distinct in their lithological aspect, as they are from the Indus erratics by their geological age. In his Memoir on the Salt-range (Vol. XIV) in a note to page 117, Mr. Wynne thus correctly, as I believe, alludes to the 'erratics' of the Indus valley:—"In other parts of the country, too, along the left bank of the Indus south of Attock, the foreign erratic blocks are too numerous and too large to be accounted for satisfactorily in any other way that I know of." That is, than by ice agency. Two of these are described in Records X, p. 124, as having a girth

[1] Choi is not on the Atlas map. It is, however, a little under 3 miles from the mouth of the Haro on the south bank of that river, and is a halting stage (with a 'sarai') on the road from Attock to Khushálgarh.

of 50 feet by 6 to 8 feet high, and 48 feet 6 inches by 12 feet 6 inches high; the former a granitoid rock, the last of basalt.

I now pass to the consideration of a clearly-written and valuable paper by Mr. Lydekker in Records XII, p. 15, in which the glacial question is treated at some length. Among general conclusions my colleague affirms that in Kashmir 6,500 feet is about the lowest level at which "undoubted evidence of former glacier action" exists. This, I think, may be true, as I have myself been struck with the remarkable absence of such evidence in the valley, though I never questioned the existence of such evidence at much lower levels in the outer hills. The cause of this, should the statement not require modification, is I regard an interesting object for future investigation. Mr. Lydekker differs also from Prof. Leith Adams in his failing to recognise any proofs of a glacial origin for the Báramula gravels, and in this I agree with my colleague. At page 30 (*l. c.*) Mr. Lydekker records his dissent from Colonel Godwin-Austen's opinion that certain granitoid blocks in the Jhelum valley below Báramula have been brought to their present position by ice action. Here I dissent from my colleague, and consider that Colonel Godwin-Austen has rightly estimated the mode of transport of these blocks in question. In support of his view my colleague goes at some length into a description of the Jhelum valley, which, being clear in language, and conveying completely my own views, I shall here quote *in extenso*. That my colleague has arrived at a different conclusion to myself, I attribute solely to the accident that he has not seen such a 'key section,' as I may term it, as I was fortunate enough to discover during last season's work in the valley of the Nainsukh, above Gurhi Habibula :—

"At Rámpur the alluvial formation contains gneissic blocks, some of which are as much as 15 feet in diameter; the whole formation is at least one hundred feet in thickness on the left bank of the river. The included blocks are all more or less rounded and water-worn, while the matrix in which they are embedded is here but little stratified. As we descend the river, the blocks of gneiss continue to decrease in size till we come upon the sharp bend in the river below Rampur; here a fresh stream of gneiss blocks has come down a tributary stream from the second gneiss mass in the Káj-Nág range: some of these blocks have a long diameter of 20 feet.

"Still continuing our survey down the river, we find the gneiss blocks again becoming smaller and smaller, and half way to Uri the alluvial deposit is seen to be most distinctly stratified. All the gneiss boulders have their long axes inclined up the stream and towards the river bed at an angle of about 30°; so that one of the flat sides is opposed to the flow of the stream, as we find to be the case in any deposit of modern river pebbles. The summit of the alluvial formation is level, forming high-level plateaux on either side of the river. At Uri we find a similar plateau, some 200 feet in thickness, formed of the red Sirmur rocks of the neighbouring hills. The pebbles in this deposit are rounded and have the same relative position in regard to the stream as the gneiss blocks higher up. A few small gneiss blocks are found in the Uri deposit."

Now all this I fully accept as a correct description of the Jhelum terrace gravels and boulder deposits, for I regard it would be as one-sided in me to

either fail or refuse to recognise the agency of water in their arrangement as I hold it to be in any opponents who fail to recognise the proofs of glacial agency concurrently present in the same area.

I do not point to well-rounded boulders embedded in a stratified deposit, with their long axes arranged with reference to the direction of the river, as proof of glacial agency; but I do point to streams of blocks not so rounded, but sub-angular and piled on one another, with little or no intervening matter, in a fashion suggestive of moraine rather than river transport. It is true the rock of which the largest blocks consist rounds off by surface exfoliation under atmospheric action; but the streams of sub-angular blocks, to which I allude, have no nearer resemblance to the water-worn boulders described by my colleague than accrues from their consisting of the same identical rock. As an instance in point I may mention, on the right bank of the Jhelum the stream of blocks which is seen to descend the Kathai stream just below the Fort of Kathai, and is buried in the surface of the high level plateau before reaching the Jhelum. These blocks are scattered about, *sometimes isolated on the surface of the alluvial plateau whereon they rest, in other places ranged in clusters or piled against each other with little or no intervening matter; and they are all more or less sub-angular, and have none of the appearance of having been washed down the valley or by the stream.* Granting, for argument's sake, that a great debacle might have washed them down, it would not have arranged them in a long thin line, heading up the valley; in a word, their arrangement is decidedly suggestive of moraine action as distinguished from fluviatile.

Mr. Lydekker adds (*l.c.*, p. 31) :—"It will be gathered from the above observations, that the whole of the gneiss blocks in the Jhelum valley have followed the course of tributary mountain streams, have not been carried across intervening ridges, and are embedded *in* an aqueous formation." To this passage I can give my cordial assent, if I may interpolate after the word 'in', the words 'and on,' which in my opinion furnish the clue to the discrepancy of opinion between my colleague and myself. The rounded blocks to which my colleague points as conclusive of fluviatile agency may be, and no doubt are, embedded *in* river deposits; the sub-angular ones on which I no less confidently rely as proving moraine agency are, I believe, always found resting, not *in*, but *on*, the above river deposits.

There is one paragraph with which I cannot agree :—"It will be gathered from the above observations that the Jhelum is now a denuding, and not a depositing, river, as it was when these alluvial formations were laid down; from which we may probably infer that great changes of level have taken place since the period of these deposits, *which may have afforded greater facilities at certain times for the movements of the blocks.*" This is far from clear. The 'change in level,' which converted the Jhelum from an excavating stream employed in deepening its bed into a depositing one, which it must have been when it refilled its valley with alluvial deposits 200 or 300 feet thick, was one of subsidence, whereby the *gradient* of the Jhelum valley, both the main channel and all its tributaries, was lowered,—the proximate cause, of course, of the deposition of the above beds: *cæteris paribus*, therefore, this change could neither

physically nor climatally have afforded greater facilities for the transport of large blocks than previously existed; rather the contrary.

In his "further notes, &c." (Record XII., p. 114), Mr. Wynne divides the pleistocene deposits of the Northern Punjab into an upper, middle, and lower sub-division, characterizing them respectively as "Northern detrital drift," "Alluvium and river drift," "Post tertiary valley or lake deposits."

It may be questioned how far the middle and lower of these sub-divisions are separable or dissimilar; but the great merit of this division is that it distinctly recognises the relative position of the 'glacial deposits' and the older alluvium, and shows how nearly on the verge of discovering the true significance of this fact Mr. Wynne was.

Mr. Wynne is, however, careful to let it be known that he disclaims glacial agency in the distribution of his 'Northern detrital drift', not only by introducing the somewhat superfluous adjective 'detrital', but by the definition he gives at page 132 (*l. c.*):—"*Northern drift.* I use this term instead of the more simple one "erratic drift," which would appear to convey to some Indian geologists a closer connexion with glacial geology than is necessary to the purpose." This disclaimer suffices to show how nearly Mr. Wynne missed recognising the essential merit of his own classification. Especially when read in connexion with what follows:—"By Northern drift, then, is here meant that influx of travelled masses which has followed the course of the Indus from the north and been distributed over large spaces of the Ráwalpindi plateau, to a distance (I am informed by Mr. Theobald) of 25 miles from the river. These blocks are easily recognisable, all along the upper Indus as far as I went, to be the same as those further down its course. *They often rest on the terraces, and some of them are of very large size.*" Mark how very nearly discovering the truth Mr. Wynne must here have been (how he 'burned,' as children say at 'blind man's buff'), could he only have recognised the significance of their not occurring *in* the terraced gravels though scattered about *on* them! Considering, too, that Mr. Wynne gives the girth of one of these blocks near Torbela as 109 feet, his disclaimer of glacial agency on its transport seems to me to savour of caution overmuch! It would, indeed, seem to be an afterthought, as in his Geology of the Salt Range, at page 117, Mr. Wynne thus expresses himself of these very blocks:—"In other parts of the country, too, along the left bank of the Indus south of Attock, the foreign erratic blocks are too numerous and too large to be accounted for satisfactorily in any other way that I know of"—that is, than by ice; and it is, I think, to be regretted that Mr. Wynne should have been led to abandon this sound view, and substitute for it the disclaimer of glacial agency in his later paper, quoted above.

At the end of the paper in the Records (XII, p. 132), Mr. Wynne notices a detached mass of limestone 127 paces in girth, which may possibly be an 'erratic' slipped down from Sirban mountain, aided possibly by ice before the intervening ravine was cut, or, as I would suggest, when it might have been sheeted over by ice; and Mr. Wynne records the discovery by myself of glacial striæ on a block of quartzite below Torbela. I mention this to express my belief that the striæ in question are not glacial, as I once supposed they might be; but

what could have produced straight, but not parallel, scratches on a hard corneous quartzite, I cannot say. They may be glacial, but their varying direction makes this very doubtful.

To revert now to my own observations during the past season. I may commence by saying that a re-examination of the ground near Jand failed to verify the occurrence of 'erratic' blocks in the peculiar silt of that neighbourhood. The occurrence of 'erratic' blocks in this silt rests on two presumed instances recorded in my paper (Records X, p. 142) of such blocks being seen reposing *in situ* and partly embedded in the silt; but from the conditions of the case, such an observation requires corroboration, and hitherto my search for a section displaying such blocks embedded in the silt has not been rewarded with success; and the glacial character of the deposit may therefore be still considered as unsettled. That this silt is a lacustrine deposit, is, I think, more than probable, and that it is really the homologue of the coarse alluvial accumulations near Ráwalpindi, when the lower part of the Sohán valley and the adjoining region along the Indus, with the Chuch Hazára plain, constituted a lake through which the Indus flowed, and which owed its origin in part perhaps to that subsidence of the whole area to which the thick alluvial deposits in the Indus valley and its tributaries bear testimony. If my suggestion is correct, that this silt is the exact homologue of the clays and gravels to the east and north, it at once explains why no erratics are found embedded in it, though more or less widely dispersed over the area covered by it, since I shall presently show that the glacial conditions whereby the erratics in question became distributed, *supervened* on (that is, after) the deposition of the gravels in question. At page 516 of the Manual, Mr. Blanford suggests the idea of lacustrine conditions as contributing to the dispersal of these blocks, with the alternative suggestion of a "*variation in the course of the Indus, and to the reversed flow of its tributaries in great floods.*" I shall endeavour to show that each of these suggestions has its share in producing the phenomena under review. The lineal arrangement of these 'erratics' in the Potwár,—one line following the general direction of the Sohán valley, whilst a parallel train of erratics passed near Jand (Rec. X., page 142), could only have originated in two ways,—either through 'moraines' descending to the Indus trough, or through floating masses of ice sweeping up the tributary valleys during a reversed flow of the streams produced by floods. And the result would not be interfered with, supposing the area adjoining the river to have been temporarily covered by a lake, as the reversed flow of the streams falling into the lake, during the rise in its waters resulting from Indus floods, would suffice to establish a direct current, mainly coinciding with the old river channels, through the body of still water of the lake at large and constituting *water lanes*, along which the erratic blocks and floating ice could be carried, and to which the linear arrangement of the blocks now seen would be due. If, however, there was no lake, the 'reversed' flow of flood would produce this lineal arrangement of erratics, as a matter of course; but the presence of a lake would, I think, no less permit of a similar distribution of the blocks, and would fully account for their presence in the situations they are found to occupy, that is, on the top of the alluvium, as near Pindigheb, for example, and Taman.

Leaving the vicinity of Jand, which may be regarded as somewhere near the centre of the supposed lake, and proceeding north, we find an instructive section of these valley deposits near Pari, on the Nára river (3 miles east-south-east from Shádipur, on the right bank of the Indus) and about 15 miles from Jand. Approaching the Indus from the south-east, along the road leading to Pari and Shádipur, we see in front of us a long stretch of rising ground, more or less parallel with the river and decreasing in height away from the banks. The edge of this line of rising ground is very rugged and broken up by denudation, and the Nára river below Pari gives a clear section of the beds, showing that the rising ground in question is simply a belt of coarse beds, whose maximum thickness is attained in the immediate vicinity of the river, and which thins out away from its channel, owing to the coarser material being at once deposited, whilst the finer sediment only is conveyed to more distant parts of the valley. The bed of the Indus is here cut deeply in Siwalik sandstones, dipping mostly at high angles. On the edge of these beds rests a thick alluvial deposit, divisible into a lower or conglomeratic portion, and an upper division of clays in which the conglomeratic element is wholly subordinate—the united thickness of both divisions along the river not falling short of 80 or 100 feet, though how much has been removed by surface denudation, it is impossible to say. The lower conglomerate is very coarse and heterogeneously composed, the largest boulders in it being of nummulitic limestone, commonly 3 or 4 feet in girth; and often sub-angular, the ingredients being evidently derived from the Chitapahár range only a few miles distant to the north. This deposit is clearly a coarse river gravel, but although very large blocks occur in it, I did not notice decisive proofs of glacial conditions—that is, any monster blocks of the Hazára gneiss actually in it. In the valley of the Nára river, however, one mile east of Shádipur, I noticed two huge 'erratics' not far apart, one of Hazara gneiss 50 feet in girth, and one of nummulitic limestone 60 feet in girth; but although these might have been derived (from the position they were in) from the coarse bottom bed above described, they might equally have been let down into the stream bed from a higher position by mere denudation, and this view is supported by other considerations I shall soon adduce. All about Pari, too, large craggy masses of limestone are scattered, which may be doubtfully referred either to this coarse bed or to ice flotation at a later period; and their distance from the river, and their being out of the direct line of its floods properly so viewed, render the latter supposition, I think, the preferable one. Above this coarse bottom bed occurs a group of clays of equal thickness, or greater perhaps, away from the immediate vicinity of the river. This clay in places contains a little kankar, and forms the general surface of the country hereabouts; and on its surface genuine erratics are here and there seen of the Hazára gneiss, which, as I believe, can have been only so brought by ice flotation; and if we regard the basal conglomerates as local deposits, resulting from the proximity of the Indus gorge (below Níláb Gásh) and the Chitapahár range, the homology between the Jand silt and the ordinary valley alluvium is clearly seen, both resting on the denuded sandstones, wherein the river has now deeply sunk, and both supporting genuine 'erratic' blocks of a later period.

Leaving now the Potwár, and crossing the Chitapahár range, we descend into the valley of the Hurroh (which joins the Indus at the rectangular bend that river makes to the west), at Nílat, where the old royal road from Pesháwar to Hindustan used to cross, and both the Haripur and Chuch plains offer some points of great interest in connection with their recent deposits and the physical changes of surface they reveal.

The Haripur plain is bounded on all sides except to the south-west by hills, and is composed of a deep alluvial deposit, the older rocks not usually appearing, away from the hills which bound the valley. South of the old cantonments of Haripur, the whole of the drainage of the valley is conveyed into the Hurroh river; whilst that to the north finds its way into the Dorh, which, after being joined by the Siran, flows into the Indus above Torbela, past the northern extremity of Gandgarh mountain, which is interposed between that river and the Haripur plain. No erratics occur in any part of the Haripur plain, and the valley of the Hurroh is wholly free from them till within a mile or less of the spot where the Pesháwar trunk road crosses the stream. Down to this point the valley may be said to be sheltered by the mass of Gandgarh; but directly the lower ridges south of Gandgarh are passed (going west), 'erratics' of Hazára gneiss, or the Indus 'erratics,' as they may be called, appear in some force, and from the spot where the road crosses continue *down the valley of Hurroh as far as its junction with the Indus at Barotha.* These 'erratics,' as I have stated, have not descended the Hurroh valley, but have cut abruptly into it from the Indus, below the sheltering barrier of Gandgarh, or, in other words, the former course of the Indus coincided with the present course of the Hurroh, west and south of that mountain. This will be rendered clear by a glance at the accompanying sketch map, whereon is marked the course of these Indus 'erratics' and their distribution in this neighbourhood; and it will be at once apparent that at no remote period the Kabul river joined the Indus—not, as now, at Attock, but close to Barotha, some 9 miles to the south. The whole of the country between the trunk road on the north and the Hurroh on the south, consists of rolling 'downs' of river alluvium, mostly sandy, with here and there a sprinkling of Indus gravel and boulders, and scattered 'erratics'—these last being specially numerous along the course of the Hurroh, as the annexed map will show.[1] Many of these erratics are of large size, 50 feet in girth or more, though of course the majority are smaller. They consist of Hazára gneiss or of limestone, which last rock has not travelled so far as the other. The sketches here given (see Plate) of one near Dakner and of another near Jand, by Mr. Wynne, will give a good idea of the general appearance of these blocks—those of limestone or of any crystalline schist being, from the nature of the rock, usually more jagged and angular than those of gneiss, which is so wont to 'flake off' at the surface.

No one, I think, who considers that the above 'erratics' (granite) have travelled from the most distant parts of Hazára, and are now seen reposing on a sandy plain, will entertain serious doubts as to their truly 'erratic' character, or that they have been conveyed by ice flotation to the positions they now occupy.

[1] See also Wynne's map, Records X, Part 3.

Erratic of Gneiss near [illegible] 4 Miles S.S.W. of Attock

T. Schaumburg, Lith.

Erratic of Gneiss below Jand and Khushálgarh

Mr. Wynne also writes as follows (Records X, p. 124) :—" *On one of the river terraces* of the Indus gorge, between Pari and Báhtar, I measured an 'erratic' mass of unfossiliferous limestone 9 feet high and 74 feet in girth, which may have belonged to any of the neighbouring limestones, from the lower nummulitic downwards, and seems to be as truly an erratic block as any of the others." No doubt this block had not travelled far, but it is interesting to find such a mass *on* an old river terrace, when the full significance is realised of such blocks occurring on the old gravels, but not in them, as would seem to have been always assumed as being the case, as a matter of course, by the opponents of glacial theories.

No less interesting, as proving the altered surface conditions now prevailing, are the indications afforded by the lower part of the Dohr valley, where it is joined by the Siran. Leaving Haripur by the Torbela road, which descends sensibly, and continues nearly parallel to the course of the Dohr, we come in sight, at about 4 miles, of what seems a low ridge stretching right across the valley and connecting the hills across the Dohr with the Gandgarh range of hills. A little to the left of this seeming ridge, and perched on the foot of the Gandgarh hills, is the village of Dari; and away to the right is Barukot. Approaching nearer, we find that the seeming ridge is breached right in front of us by the Dorh, after being joined by a small stream from the south, when it flows on and joins the Siran close to the village of Tapli. The road along the bank of the Dohr here affords an excellent section of the coarse boulder deposits which seem to constitute the ridge in question. On the Gandgarh flanks, round which the road winds, the deposit consists of coarse gravel and boulder conglomerates, with a good many Indus erratics strewed about the hill side and lying in the bed of the stream. One of these near Tapli was measured by Mr. Wynne (Records, XII, p. 132) and found to be 109 feet in girth, and others of about half that size are pretty frequent lower down. *None of these have descended the Dohr,* and at first sight the impression was a very strong one that the seeming bank on which Barukot stands, littered over as it is with 'erratics,' was a moraine which had descended the Siran valley and been breached by the Dohr prior to its effecting a junction with the former river. An examination of the ground about Barukot, however, totally dispelled this view and revealed a very curious and anomalous condition of things. The ridge in question was found to be a remnant of the same old alluvium constituting the Haripur plain, and cut into a tongue by the Siran on one side of it and the Dohr on the other. This spit, or tongue, is thickly covered with Indus *boulder gravel* and some *erratics ;* but not a single erratic or boulder encroaches on or is found in the Haripur plain, which is here below it in level; and I do not think any of this gravel is discernible over 100 yards beyond its sharply-defined boundary at the village of Dari, or south of the Dohr, which ran under the Barukot ridge.

In the valley of the Siran, not a boulder or erratic is to be seen, and the surprising inference is unavoidable that the capping of boulder gravels and erratics has been washed over the Haripur alluvium from the Indus itself. At first sight it would seem as if these erratics and boulder gravel or drift must have *ascended* the course of the joint Dohr and Siran valley, but a glance at the map and the space covered by these 'erratics' will show that supposition is not necessary. But

the remarkable thing is, that if the Indus current brought this gravel over the top of what now form the Barukot ridge, it did not pass bodily round Gandgarh hills and flow through the plains east of Gandgarh.

The accumulation of 'erratics' rafted by ice, up a backwater of a tributary during a flood in the main river, could be easily understood; but not so a thick deposit of boulder gravel, unless on the supposition that the well-rounded character of the boulders is no bar to their being a veritable glacial deposit also. And this conclusion is, I think, the only one admissible. A strong current alone (if we dismiss the idea of ice flotation) could have accumulated the coarse cap of boulder gravel and clays here seen, between Dari and Barukot; but if the Indus flowed as far as Dari in full current, it must have flowed further towards Haripur; but this it unquestionably never did, and the conclusion therefore is that this deposit is one formed by floating ice charged with clay and boulders, which accumulated in the 'cul de sac' of the Dohr mouth and deposited its burden on melting all over the area submerged by the Indus flood water. The reason why the Indus did not flow further into the Haripur plain is of course that the plain was then higher than now, and barred the further advance of the flood waters laden with 'erratics' in that direction. As I have remarked, the boundary of this coarse boulder deposit is very sharp and defined, and this belt of gravel has served to check denudation over the area covered by it, while the undefended alluvium of the Haripur plain has been greatly lowered by the scour of the Dohr and its feeders, the result being the scarped gravel-capped ridge on which Barukot stands. Parts of this deposit have a certain resemblance to the *Talchir boulder bed*, in consisting of a compact clay in which boulders are disseminated, as may be seen in the cuttings on the Torbela road, though the bulk of the deposit is a coarse stratified boulder gravel.

The following localities for 'erratics' may be specified. From Barukot to Torbela along the course of the Dohr, and on the left bank of the Indus for some miles above Torbela, some of these gneiss erratics are over 100 feet in girth. Near Attock small erratics, as well as rounded boulders, are freely scattered about to a level of from 300 (or perhaps 400) feet, or thereabouts, above the present bed of the river. South of Háji Shah a gneiss 'erratic,' some 20 feet in girth, is lying in a field, and some smaller ones near it. One mile north-east of Campbellpur is a gneiss 'erratic' 30 feet in girth, and in the low ground near Campbellpur, an enormous number of 'erratics' from 20 to 30 up to near 100 feet in girth. The largest of these are limestone, but some of the smaller ones are of gneiss. South-east of Campbellpur, near the village of Boliwála, a little outside, seemingly, the limits of the Indus bed, or Haro (Hurroh) channel as it now is, a few 'erratics' are seen 12 feet or more in girth; and these blocks were probably stranded there during floods. At 1½ mile east-south-east from Boliwála is a granite 'erratic' in a field by itself, with 'cup marks' on the top.

The whole country in this direction, towards Kala-ka-serai, is an old high level alluvium, co-extensive with the Indus alluvium of the lower Haro (Hurroh) valley, but no erratics save those near Boliwála on its edge were noticed in it. Some 3 miles north-east of Choi, on the road from Campbellpur, a huge and jagged erratic of quartzose gneiss occurs. It has spontaneously broken up into

several pieces, but must when whole have measured some 60 feet in girth. In a word, the whole country is dotted with these erratics from the point where the Peshawar road crosses the Haro, to the mouth of that river at Barotha, and thence to Dakner in the Attock road.

Across the Indus, in a north-west direction, stretches the Yusufzai plain, the broad open valley of the lower portion of the Kabul river. This plain consists of a thick deposit of alluvium laid down by the Kabul river and its tributaries, and may be partly at least of lacustrine origin. I made one traverse across it from Nowshera to Hoti Murdán. Opposite Nowshera is a low range, over which the road is carried. To the right the range sinks down and is covered over by alluvium. Resting on this alluvium, were a good many large limestone blocks, which seemed to have travelled from the neighbouring range, rafted as I imagine by ice. A little west of the road, on the slopes of the range, I noticed a large block of limestone "perched" on three smaller blocks on the alluvium. These blocks had none of the appearance of being artificially arranged, and if not, this must be considered a truly '*perched*' block. None of these blocks exceed 6 or 8 feet in diameter, and they are all derived from the ridge to the west of the road. I noticed no erratics along the line of road from Attock to Peshawar, and it is pretty certain the Indus 'erratics' never invaded the Yusufzai plain. This I at first thought strange, till I discovered that at the period of their transport, the Indus ran (as explained) far south of its present course and east of Attock to Barotha, which may help to account for no erratics being seen north of Attock, though no doubt the valley of the Kabul river will be found to have its own proper 'erratics' of the period when search is made for them.

The Pakli plain, or valley north of Mánsahra, and the Ughi plain to the north-west, both present the same general feature; they are both surrounded by hills, the former being traversed by the Siran river, the latter by the Ughi river, falling into the Indus near Derband. In the Pakli valley the alluvium of the Siran river is some 300 feet thick or thereabouts, of which an excellent section is seen on the road from Mánsahra to either Ughi or Shinkiári. No 'erratics' are seen in the valley gravels, which are simply ordinary river gravels and clays interstratified; but large boulders, which I regard as erratics, are occasionally seen, strewed over the surface. In the open part of the valley these blocks are exceptional; but a few miles from Shinkiári, where the Siran debouches from the hills, and all up the Siran valley, below and above Shinkiári, erratic blocks are very numerous at all levels resting on the surface of the ground.

I have not examined the Ughi plain in detail, but at the foot of the Susalgali pass leading from Mansahra to Ughi, and a few miles from that place, I noticed a few granite blocks resting on the alluvium, precisely as noticed near Shinkiári.

It is, however, in the valley of the Nainsukh or Kanhar river that the clearest sections are seen demonstrating the relations of the 'erratics' of the glacial period to the older alluvial deposits.

The Nainsukh falls into the Jhelum opposite Rara, and at Gurhi-Habibulla on the direct road from Mánsahra to Muzafarábád, is a muddy brawling glacier stream, spanned by a handsome suspension bridge. In the bed of the stream

are numerous 'erratics,' and I determined to trace them to their source, though I hardly anticipated so clear and decisive a result as rewarded my efforts.

The valley of the Nainsukh or Kanhar river, draining the Kaghán valley on the north, is very narrow with a very great fall, and bounded on either side by ranges of hills with peaks from 8,000 to 15,000 feet or more. On nearing Garhi Habibulla from Mánsahra enormous 'fans' are seen descending from the range across the river (to the east) to the stream. On the west bank, however, the road from Garhi to Kaghán lies along the bed of the stream, and is skirted in many places for miles by a steep cliff of old river gravels, through which the brawling river has cut its present bed. This cliff varies from 80 to 100 feet or more in height, and the thickness of the gravels, or old alluvial deposits, of the Kanhar river may be 150 or 200 feet or more, which is neither easy on a cursory visit, nor material to determine. In this cliff every pebble is clearly exposed, and the striking fact was soon established beyond all question, that no 'erratics' existed in this deposit from top to bottom. Yet, they were plentiful enough in the bed of the stream, from 15 to 60 feet or more in girth.

Where, then, did they come from?

About Garhi, the gravel of this old alluvium is not very coarse, that is, it is a gravel in which boulders of one foot in diameter are rare and conspicuous for their size, contrasted with the bulk of the materials around them. Ascending the stream, however, the deposit increases in coarseness gradually, till near Byssia, boulders of from 1 to 10 feet in diameter have become pretty numerous, but no erratics or boulders of a larger size. The section of the deposit is clear, and the fact indisputable. A mile below Byssia, the road winds round an almost overhanging cliff of these gravels. Here an occasional boulder of 3 feet in diameter may be detected, though such are rare; whilst in the river bed beneath huge 'erratics' are plentiful, and a little way higher up numbers occur, two of which were over 70 feet in girth. The largest 'erratics' in the river bed are of the usual Hazára gneiss; whereas gneiss is not prominent in the terrace gravels, and only in small boulders, the larger blocks in these beds consisting of limestone, hard schists, or trap rocks. It, therefore, became perfectly clear, even before reaching Byssia, that no erratics were being brought down by *any* agency during the period these old gravels were being laid down.

This deduction, which is beyond challenge, is the key to the glacial phenomena of the entire sub-Himalayan region.

Byssia is built on a low terrace of coarse gravel, as described above; but it is not more than a third as high as the terrace near Garhi. On the opposite bank of the river, however, a part of the old alluvial terrace is seen of the usual height, so it is clear that *some agency* has operated to reduce the height of that portion on which Byssia stands. Close to the village some scattered 'erratics' are seen, and at the village graves, a line of erratics commences and extends thence right up the valley. The annexed sketch (see map) will illustrate the general feature of the ground. The erratic blocks are of the ordinary character of the Hazára gneiss erratics; and it would seem to be the continuation of this line, engulphed in the river, which I noticed above as yielding blocks 70 feet in girth.

The origin of this stream of 'erratics' is not far to seek. Ascending the valley above Byssia, the village of Shahwal is soon reached, standing on the further bank of a small stream. Down this stream has descended what those who please may call a 'fan,' but what I term a 'moraine,' disintegrated perhaps by subsequent stream action, but which consists of an enormous stream of granite blocks from the range behind, up, say, to 40 feet or more in girth. This stream unites with a similar one which has descended the main valley, and is just an old lateral moraine. A little way below this a small streamlet of blocks has forced its way down a narrow valley,—I may almost say cascaded down it,—and joining the larger lateral moraine of Shahwal has helped to swell the stream of blocks all tending towards Byssia. The little valley alluded to is barely 50 yards broad with steep V sides, and yet several of the blocks piled all on top of each other are from 40 to 70 feet in girth and completely jam the gorge. The fall of this gorge is steep, and I doubt if it ever contains a couple of feet of water, and that must be often broken up into foam, cascading over these rocky masses, the arrangement of which is shown in the outline section, fig. 2 (see map).

In bringing forward this section, however, I claim to be understood intelligently, and not to be confronted by inapplicable syllogisms of the well-known V order of argument of the antiglacialists. Whoever, indeed, looks here for ice marks on the rocks will be disappointed; nor can the obvious history of the gorge lead to any other anticipation. The gorge originally gave passage to a small glacier, as no other means I consider adequate to the transport of the rocky masses found in it. The base of the glacier no doubt was of the usual shape, and at a much higher level than the present bed of the V-shaped gorge. On the disappearance of the glacier, stream action commenced, and, aided by the scour of the sharp granite detritus, soon effaced the old valley and cut down the present V-shaped channel into which, *pari passu*, the 'erratic' blocks subsided. To imagine that such a piddling stream as could ever have found its way down here, brought down these huge blocks, is simply absurd. The argument might be adduced for the large stream under Shahwal, but not here.

The constitution, however, of the old river gravels disproves the idea that stream action which produced them had any influence in bringing down the 'erratics.' The material of which the 'erratics' consist, existed then, as now, close at hand in the adjoining ranges, but the *power* to move them was wanting, till the supervention of glacial conditions during a later period. It would be mere repetition to describe similar cases all up the valley, the 'erratics' everywhere reposing on the river gravels and being obviously referrible to subsequent ice action and not to river transport.

The consideration of the above facts affords a key, in my opinion, for reconciling the opposing views held, regarding the share played by ice in the formation of these recent deposits. The presence of huge 'erratics' strewn over the outer hills is appealed to by men like myself, supporters of glacial views, as a proof of the reality of such agency, and is opposed by other observers on the ground that such blocks are embedded in deposits of palpably fluviatile origin, but *till now* it has never been shown that both advocates are in a measure right, though in reality the erratic blocks merely rest on and are not really embedded, save

superficially, in the river deposits. To quote an example: Near Riási, on the Chináb, an enormous limestone 'erratic' was pointed out by me to my colleagues, Messrs. Medlicott and Lydekker, in proof of glacial conditions having necessarily been involved in its transport, but as it *rested on* a thick deposit of river gravels, my argument was held to be discredited. In these cases, *as in all others that I have seen,* this 'erratic' block rested on the river deposits, but the true significance of this fact was not then fully comprehended by any of us, and was looked on as fortuitous, in place of being the normal position of these blocks with reference to the old river gravels.

Considering then, as I do, that the distinct relation of a newer glacial deposit, consisting mainly of 'erratic' blocks, to an older fluviatile deposit, as established beyond controversy by the sections seen in the Kanhar river, and the consequent extension of an isothermal line compatible with the existence of glaciers, to so low a level as between 2,000 and 3,000 feet in the Northern Punjab, I would here add a few words on the various objections which have been adduced against the possibility of such a condition of things elsewhere.

In my paper on the ancient glaciers of the Kángra district (Records VII, p. 86), I endeavoured to show that the 'erratics' originally described by Mr. Medlicott as 'glacial debris of the Dhauladhár' (Memoirs, III, Part 2, p. 155) were really due to moraine transport; but I did not then comprehend the true key of their seeming anomalous relation to fluviatile deposits wherever they are seen to rest. I did not then apprehend that they only rested on such deposits and were not enveloped in them. But I *did comprehend and claim to have distinctly asserted that they were of moraine origin, and, what is more, that there should be no possible misapprehension* (though in this I was vastly mistaken), I divided the area into three vertical zones or areas, naming each respectively pre-glacial, glacial, and post-glacial. I quote my own words (*l. c.* p. 93). "The Kángra district may be ideally divided into three vertical areas or zones:

*Firstly*, a pre-glacial area embracing the whole country, which contributed from peak to plain to the *genesis*, and development of the glaciers under consideration; speaking roundly and without any measured data to check the estimate, the above zone or area embraces all ground higher than from 250 to 300 feet above the mean level of the present streams.

*Secondly*, a glacial area proper, embracing the entire area either occupied or excavated by the glaciers, which may be approximately fixed as commencing at the bottom of the above division and terminating below, at a level of about 150 feet more or less above the mean level of the present streams.

*Thirdly*, a post-glacial area, embracing the whole of the ground below the basal limit of the last division and the result of aerial denudation subsequent to the cessation of glacial conditions."

The precise figures used are, of course, open to correction, but no possible exegesis can render the above words *clearer than they are*, as they stand, and yet Mr. J. F. Campbell, F.G.S., with my paper in his hand, actually potters about, looking for glacial markings within my *post-glacial area*, and finding none, pronounced my theory discredited (see Journal, Asiatic Society of Bengal,

Vol. XLVI, Part II, 1877, Campbell on Himalayan glaciation). I shall not discuss Mr. Campbell's brochure at length, simply because a man who professes to refute the views of another, which his every word proves him not to have comprehended, cannot be profitably argued with, but some of Mr. Campbell's arguments, being of a general nature and the joint property and stock-in-trade of all anti-glacial geologists, may be here noticed. It may be here mentioned that as Mr. Campbell has not realised the conditions which I believe really obtained, many of the arguments adduced are really and truly beside the question; but "n'importe."[1]

Arguments why glaciers never descended, as ascribed by me, to within 2,000 or 3,000 feet of the sea in Northern India:—

I.—The course of these suppositive glaciers lies along V-shaped valleys, which indicate aqueous, not glacial, erosion.

Undoubtedly, as the remarks previously made show, the glaciers descended *on top of an enormous accumulation of gravels filling up the old valleys of a V shape.* These gravels were only partly cut down and cleared away by the glaciers; and partly to this, and partly to the post-glacial action of streams, the contours of the ground are all of the V kind. Argument No. I is consequently worthless.

II.—No glacial markings are found on rocks *in situ*, as must have been the case had each river bed given passage to a glacier, as asserted.

To this I remark, that search for such marks seems generally to have been made by Mr. Campbell in places where, if my theory is correct, no glacier ever descended, that is, in contact with the present rock surface; and that the ordinary roads leading up our large river valleys lie, as a matter of fact, below the level, where ice action would have left its mark. Then, again, so much of the ground in question is made up of rock unfitted for, or incapable of, retaining 'ice markings;' and when the rock *is* fitted, it forms crags above the paths now used, accessible to few living things, save the wild goat and his natural enemy, the human hunter. This argument is therefore no better than the last.

III.—Absence of striated blocks within the area asserted to have been traversed by glaciers.

To this I reply that the rock which has furnished the largest and most numerous 'erratics' (granitoid gneiss) is wholly unfitted for the retention of any

[1] Mr. Campbell's observation was very far from being so preposterous as Mr. Theobald would make out. Notwithstanding the definitions quoted above—a general meaning for which (and it would be ridiculous to attach a rigorous meaning to such definitions, where the conditions necessarily admit of exceptions) was sufficiently obvious, in the prevailing erosion of the river gorges below the level of the old gravels—it was a perfectly fair, or even inevitable, inference that any rock-surface supporting the old gravels was one on which, according to Mr. Theobald, a glacier had travelled. Mr. Campbell found such a surface freshly exposed, but without any trace of the markings required by such conditions. There might remain a dispute about the identity of the gravels at that spot, but this would altogether change the venue of the case. It would seem that Mr. Theobald did not at the time comprehend his own brochure otherwise than Mr. Campbell; for in a subsequent notice (Records X, p. 140) of the opinion that had been passed upon the supposed glaciers of the Kángra valley, he makes no allusion to the rejoinder which he now (as suggested by his recent observations) urges with such ultra ferocious vigour—a triumphant style which by no means helps to impart the conviction it ostensibly implies.—H. B. M.

such marks; and also that the deposits, whereon *these erratics rest*, being of fluviatile origin, have naturally been searched in vain for such evidence; and lastly (whatever may be the reason therefor), in India, scratched blocks are so rare as almost to be exceptional in the vicinity of existing glaciers. The absence or rarity of 'scratched blocks' at low levels is merely, therefore, a negative argument, which, if of any force, might be used to disprove the existence of glaciers, where they are now actually to be met with. Argument No. III therefore is as little cogent as its predecessors.

IV.—Water power is sufficient to account for the transport of the blocks termed by me 'erratics' and referred by me to either floating ice or 'moraines.'

This is an argument which anti-glacialists never weary of producing, in season and out of season, and requires therefore some consideration. As the Kangra 'erratics' range up to 150 feet in girth, and many of them of very large size stand well out in the plains, away from the hills and in cultivated ground, I have no belief in such a vehicle for such blocks. How the case might be in a river bed is another matter; but standing, as many of these erratics do, in open ground, the idea is not tenable for an instant.[1]

Mr. Campbell remarks: "I am quite certain that the Kángra erratics are large 'pebbles' washed out of the 'cads'[2] by heavy floods." Now, if these erratics were met with *only* in the 'cads' (khuds) or more numerously in the khuds, than out of them, Mr. Campbell's argument would have a colourable basis; but the reverse is the case, and the largest blocks are found in spots where it is impossible they could have been washed into out of any possible khud.

To descend, however, from the general to the particular. Let us examine the case of how Indian rivers do deal with masses, such as Kángra 'erratics.'

In my Kángra paper I say: "At Sujánpur, the moraine of the Sujánpur glacier is seen pushed right across the present channel of the Beas, at a *much higher level* than that of the present stream, which has made a clean and deep cut through it; yet, though the 'erratic' blocks scattered round the travellers' bungalow at Sujánpur and all over the truncated end of the moraine on the opposite side of the river are of a large size, not a trace of one can be seen in the river bed beneath."

This disappearance of the 'erratics' in the bed of the stream may be accounted for in three ways. There is, first, the 'rush of water' theory of the anti-glacialists, and, doubtless, if a piddling stream could have brought these blocks as far as the banks of the Beas, the bigger river could have easily moved them on; in which case we should expect to find them congregated in a lump or bar, at the first spot where the reduced velocity of the river outside the hills deprived it of the

[1] The fallacy of assuming that the surface on which these blocks now lie is that on which they were deposited, has been already indicated (Jour. As. Soc., Bengal, XLVI, Pt. II, p. 13).—H. B. M.

[2] I am indebted to Mr. Medlicott for kindly pointing out to me that the word 'cad' which I had (in my ignorance) supposed to be a local term, current in the Highlands of Scotland, and pure Gaelic for gravels, was merely a novel mode of spelling the common Indian word 'khud' = a steep valley.

necessary power required to carry the block onwards; but no such accumulation is seen, and hence it is very doubtful if the river ever acted in this manner. Secondly, the blocks, after being engulphed in the main channel, may be supposed to have been destroyed by wear and tear and the impact of rolling masses during floods. Such a process, no doubt, disposes of a vast bulk of materials in every stream; but it is a process probably more active in mountain torrents with a steeper fall, but less actual body of water than the Beas. Thirdly, there is the scouring action, which during floods undermines big obstacles to the current, and eventually entombs them in the grave thus produced, levelling the gravel flush over the spot where they have disappeared; and this I believe to be the case in the Beas, and the true explanation of the paucity of 'erratics' in its channel.

To consider now the case of a river whose velocity largely exceeds that of the Beas at Sujánpur. The Jhelum below Uri fulfils this condition, as the stream is there in many spots a 'race,' and the bed of the river is full, moreover, of these very erratics, derived from the lofty peaks of the Káj Nág adjoining. What water can do in a stream bed with such 'erratics' we here see. The effect of the rapid stream is to clear away all gravel and smaller boulders, leaving the larger masses packed against each other, with great cavernous interspaces between. Over these masses of rock, the waters cascade in sheets of foam, or force their way in hissing jets between or beneath them; but the rocky masses themselves are immoveably packed by the very force and agency of that element which some would regard as capable under such circumstances of sweeping them away Not a bit of it—occasionally a blasted pine, whirling down stream, gets swept between the blocks, and by its leverage wrenches them apart; but this is a passing incident, and its effect, so far as any onward and progressive movement of the blocks is concerned, is inappreciable.

These two instances of the Beas and Jhelum illustrate the power possessed by water under the ordinary operations of nature to move masses like the sub-Himalayan erratics; but the necessity of weighing the argument is almost dispensed with from the now established fact (presuming the Kángra and Hazára deposits to be homologous) that the erratics do not occur embedded in the old river gravels, but simply resting on them.

How, too, I ask, on the supposition advocated by Mr. Campbell, that the '*erratics*,' as I consider them, are merely masses transported down a '*fan*' by stream action—how, I ask, comes it, that they have crossed over the Beas from north to south, as shown in my map above Sujánpur. It is impossible that the materials swept into a river down a 'fan' should cross its channel and be found on the opposite bank. With the old glaciers the case was different. They coincided generally only with the present valleys, but not with the existing river beds; and hence, as in the case of the 'erratics' on the south bank of the Beas at Sujánpur, their moraines were breached by the rivers which succeeded them. The same argument and the same latitude will not apply to any supposed rivers, as agents in producing this arrangement of 'erratics;' as, supposing the Beas (as is a simple supposition, quite possible) to have formerly held the more southern course, which I suppose the glacier here did, and to have run south of where the 'erratics' in question now occur, yet it is impossible to suppose that the river

can have cut its way back north into its present course without removing, in so doing, the 'erratics' which stand in a position which would, under such circumstances, have been its channel for a certain period. The contour of the ground, too, is opposed to the idea of the river having ever flowed, at the spot, more to the south, so that the 'fan' theory of 'erratic' transport wholly breaks down.

The following notes, penned so far back as 1871, may be here quoted, as the views then advocated are strongly corroborated by the foregoing results of last season.

"The interest which attaches to any well-defined traces of former glacial conditions, away from the immediate vicinity of the main Himalayan ranges, induces me to bring forward such an instance (as I believe it to be) on the flank of Jogi Tillah, the well-known hill near Jhelum, and which must, if substantiated, offer considerable support to the view of a former more extensive glaciation in India than is generally supposed, and not dependent on any present local features, orographical or hypsometrical.

"Jogi Tillah, which rises somewhat abruptly from the plains, is situated 16 miles west-south-west from Jhelum, and may be regarded as the most easterly termination of the Salt-range, though severed from it by some complicated faulting and the channel of the Búnhar river. The mountain itself is a wedge of rock forming an epitome of the Salt-range strata, and displaying at base the devonian salt marl on the one hand, whilst on its opposite slope a thin belt of nummulitic limestone dips at a steep angle beneath the extended newer tertiaries which form the great Potowar plateau. As the dip of the beds is to the north-west, the scarp of the hill faces the south-east, and below the scarp, the hill side falls rapidly away over a talus of fragmentary blocks deeply excavated by ravines which furrow the newer tertiary beds at its base. Viewed from a distance, the profile of the outer hills immediately beyond the scarp of the mountain is peculiar, the outline being that of a long, flat hill, with a slope outward of less than 10,° though what is seen is really the profile of one of many long ridges, separated by narrow valleys, deeply excavated in the soft tertiary sands and clays. So far there is nothing peculiar, nor are any (at least prominent) traces of glacial action met with either to the east or west of the hill, or over the flat Potowar plateau stretching away for miles to the north of it. For a narrow space, however, of about 3 miles west of Hún, over a belt of ground corresponding with the loftiest point of the mountain, the whole surface is more or less thickly covered with blocks, irregular and sub-angular, of the rocks forming the mass of the hill and presenting all the appearance of having formed part of an enormous moraine, or group of moraines, which swept down with a grand curve a little west of Hamula, and thence on to within a similar distance of Hún, both villages standing just outside of the great stream of fragments. On the top of the ridges, now some 200 feet or more above the present streams, these fragments are thickly packed, but they are also seen strewed over the sides of the hill and choking up the beds of the streams. The general relations and arrangement of these blocks are

nowhere better seen than on the road from Hún to Hamula, and just where the road reaches the small stream west of the latter village, the whole country betrays signs of being littered over with moraine debris, though all, if I mistake not, subsided through their gravity and the gradually washing away of the soft tertiary beds whereon they once rested, and not actually *in situ*. This is clearly seen by tracing the blocks up the steep slope of the hill to their undisturbed place at the top, the top being the long sloping ridge, seen in all distant views of the ground as gradually sloping from the base of the scarped side of the mountain.

"On the top, then, only, of these ridges (no doubt once an extended and continuous plateau) the undisturbed moraine materials are seen, but beyond, on the lower ground, and on the sides of the hills, the materials are distributed, under the influence of ordinary denudation and gravity.

"The blocks which form this great flood of stones are irregular in shape and sub-angular, of no very great size, 2 feet in diameter, perhaps being a fair mean, though some larger ones are interspersed here and there. The largest remarked by me was barely 8 feet in length, and was split into three pieces, where it lay, most probably, by the action of frost, to which may be attributed the absence of any large fragments. The majority of blocks consisted of the magnesian limestone, or some of the sandstones found in the hill; but the red sandstone, overlying the salt marl, though not absent, was scarce, and the few specimens seen were much decayed from the joint action of saline infiltration and the consequent disintegration of the stone through the action of moisture and frost.

"That these stones all descended from the scarp of Jogi Tillah is clear, but *how* is the question. The ground covered by these blocks may be roughly taken as some 3 miles in breadth opposite the highest peaks of Jogi Tillah, whilst the flood of stones extends over 3 miles or more from the highest peaks. Now the horizontal catchment area opposite the highest scarp is not appreciably greater than on an equal breadth opposite the less elevated portions of the mountain, so that had mere streams been the motive power, we should have to account for a local debacle of stones for which no adequate explanation through local stream action was available; whereas in the case of a glacier, it is clear that the magnitude of the associated moraine would bear a more or less close ratio to the altitude of the rocky face from which the glacier originated, just such a relation, in fact, as these scattered masses display with relation to the highest point of the mountain.

"Three miles may seem a distance not too great for these blocks to have travelled during the countless centuries during which the streams have been lowering their channels from the old high level at which they once ran—the old glacier level in fact; but such a supposition leaves out of sight two points: first, that though such small streams as descend from Jogi Tillah are capable of a very powerful erosive action on the soft beds through which they run, their direct transporting power forwards as regards large subangular masses of stone is almost *nil;* and, secondly, that the great bulk of debris, which I term a 'moraine,' is certainly transported, and that a clear distinction can be observed between the high level bulk of the deposit, which may be regarded as the material

as left, *in situ*, by the cessation of the transporting cause, and the subsidiary effect of stream cutting which has since been going on, allowing the lapse from the higher level of the "moraine" matters by simple gravity into the newer and ever-deepening channels. There is thus a "consensus" of arguments all tending to support a glacial origin for the blocks in question.

"There is the general appearance so suggestive of a moraine in the arrangement of the coarse materials, and the marked and definite sweep they assume west of Hún and Hamula. Then there is the marked relation of this band of debris to the highest part of the hill, which might of course call for no remark if it was confined to a mere talus along the base of the mountain, but is very significant when it is found stretching outward at a high level in a manner hardly compatible with mere fluvial agency, and there is the difficulty of admitting the power of streams to produce such a result under the peculiar physical and surface conditions of the neighbourhood. Finally, it can hardly be questioned that Jogi Tillah lies well within the isothermal limits of former glacier extension, since I have shown that at the period in question that line embraced the southern flanks of the outer hills down to the plains west of the Jumna."

The above extract from my notes is given with trivial verbal alterations, precisely as it was written in 1871; indeed there is no call for any alteration. Both Mr. Medlicott and Mr. Lydekker accompanied me over the ground, and they were much struck with the appearances which I refer to glacial conditions, though I believe their verdict at the time was one of 'not proven.' It was then certainly more bold to adduce such a cause than it would be now, after so convincing a demonstration of glacial agency at low levels has been made out; but I had previously discovered symptoms of glacial influences to the east, which, if not conclusive *per se*, had their proper weight in determining my own conclusions. I will mention a few—not that I insist in every instance that they are absolutely indications of glacial agency, but that such agency seems the most probable explanation thereof, and, with a view to direct future observers to these obscure features, that their true bearing may be better elucidated. In the northern part of the Jhelum district, in the vicinity of the Jhelum river, a noteworthy feature in the landscape is the presence of flat, high level plateaux. These are but thinly covered by surface alluvium, and are not portions of old lake beds, but consist of sandstones with various dip planed down flat in a manner which makes it difficult to refer such to the result of wandering stream action. These flat plateaux are sometimes slightly inclined, and the most natural explanation of this particular surface configuration is 'ice action.' It is a feature I have nowhere seen noticed or alluded to by previous writers, and I consider it one which merits further study.

The occurrence in the valleys of moraine materials, disposed as I have described in the Kunhar valley, I shall not here allude to at length, as such cases are rarely so clear as seen there, and I may have an opportunity of re-examining some spots where such deposits are in force, as in some tributaries of the Chináb. I will, however, mention one case of a transported block which I think can be due to none save glacial agency. It is a limestone block lying on the stream, 12 miles south-west from Riási, on the Chináb, between the villages Bardol and

Karkeli. This block of limestone has been derived from the limestone range to the north near Poni; but the entire drainage area within which it lies is composed of Siwalik sandstones, and it must have crossed the present watershed before the excavation of the existing valley. The Chináb here debouches from its rocky gorge into the more open valley below Riási, and flows through a very thick coarse boulder deposit, 4 miles broad and 8 miles in length, measured along the river, which deposits tail off, and rapidly diminish as we recede from the river, and are in my opinion largely composed of the re-arranged glacial materials which must have filled the Chináb valley at no remote date, and I refer the limestone block near Bardol to the same agency and period as that to which I attribute the erratic block previously mentioned as lying on the top of a thick river gravel near Riási. At Bardol, however, the block in question has subsided into the valley by the removal, by denudation, of the looser materials whereon it rested; whereas near Riási the other block is still resting in nearly its original position, on the undisturbed gravel at a high level above the river. No doubt numerous similar cases occur; but this one may be particularised, as there is no ambiguity regarding its position and relations.

## USEFUL MINERALS OF THE ARVALI REGION *by* C. A. HACKET, *Geological Survey of India.*

Although the Arvali region does not abound in mineral wealth, still it contains several extensive mines from which, in bygone times, large quantities of copper and lead ores have been extracted, and a number of small pits or burrows where ores in small quantities were found.

None of these mines were worked deeper than a few feet below the water level on account of the difficulty of raising the water. In some cases, however, when the mine is situated on a hill, an adit level has been driven into the hill to drain the workings and cut the veins at a lower level in hope of finding richer deposits; but I believe, both in the case at Ajmere and Daribo, these hopes were not realised.

All these mines, with the exception of those worked for iron, are now abandoned, and the workings filled with water or fallen together, and so little is now seen that it is impossible to form an opinion of their value.

The ore occurs either in small discontinuous veins or thinly disseminated through the rocks. In no case is there anything like a continuous vein or lode exposed.

The following is a list of the minerals, and the localities where found:—

### COPPER.

| | | Atlas sheet. No. |
|---|---|---|
| Singhána ... ... | Shaikhawáti, Jeypore ... ... ... | 49 |
| Khetri ... ... | | |
| Daribo ... ... | South of Kho, Ulwar ... ... ... | 50 |
| „ in the ridge 1¼ miles to the west | ... ... ... ... | 50 |
| Bhangarh ... ... | Ulwar ... ... ... ... | 50 |

| | | Atlas sheet No. |
|---|---|---|
| Kushalgarh | Ulwar | 50 |
| Baghani | Do. | 50 |
| Partabgarh | Do. | 50 |
| West of Nabaro<br>West of Udhala | Near Sainthal, Jeypore | 50 |
| South-east of Garh<br>Lalsot | Lalsot hills, Jeypore | 50 |
| Babai | Shaikhawáti, Jeypore | 50 |
| Nithahar | Bhurtpore | 50 |
| Datunda | Boondee | 34 S.E. |
| Rewara | Near Gangapur, Oodeypore | 34 S.W. |
| Ajmere | Near the Jail | 34 N.E. |
| Tasing | Mandan hills, Ulwar | 50 |
| Jasingpura | Near the railway, Ulwar | 50 |
| Gugra | 4 miles north-north-east of Ajmere | 34 N.E. |
| Rájgarh | 10 miles south of Ajmere | 34 N.E. |
| Rajauri | Near the above | 34 N.E. |

GALENA.

| | | |
|---|---|---|
| Táragarh hill | Ajmere | 34 N.E. |
| Ganespura | 30 miles south of Ajmere | 34 N.E. |
| Indawás<br>Gudha | Thana Ghazi, Ulwar | 50 |

IRON.

| | | |
|---|---|---|
| Bhangarh<br>Rájgarh | Ulwar | 50 |
| Karwar | Hindaun, Jeypore | 50 |
| Ajmere | Near the Jail | 34 N.E. |
| Gangár | Oodeypore | 35 S.E. |
| Bhairompura | Boondee | 34 S.E. |

NICKEL AND COBALT.

| | | |
|---|---|---|
| Bhangarh | Ulwar | 50 |
| Babai | Shaikhawáti, Jeypore | 50 |

ZINC.

| | | |
|---|---|---|
| Jáwar | Oodeypore. | |

RUTILE.

| | | |
|---|---|---|
| Motidongri ridge | Near Ulwar | 50 |

PLUMBAGO.

| | | |
|---|---|---|
| Sohna | Gurgaon | 49 |

GOLD.

| | | |
|---|---|---|
| Sohna | Gurgaon | 49 |

KAOLIN.

| | | Atlas sheet No. |
|---|---|---|
| Kussumpura ... | ... South of Delhi ... ... ... ... | 49 |
| Bachára ... | ... Ulwar hills ... ... ... ... | 50 |

GARNETS.

| | | |
|---|---|---|
| Sarwár ... | ... 20 miles south-east of Nusseerabad ... ... | 34 N.E. |
| Rájmahál ... | ... Jeypore ... ... ... ... | 34 N.E. |
| Meja ... | ... Oodeypore ... ... ... ... | 34 S E. |

ROCK CRYSTAL.

| | | |
|---|---|---|
| Aurangpur ... | ... 15 miles south of Delhi ... ... ... | 49 |

MARBLE.

| | | |
|---|---|---|
| Makrana ... | ... Jodhpore ... ... ... ... | 33 S.E. |
| Jheri ... | ... Ulwar ... ... ... ... | 50 |
| Raialo (Raiwala) ... | ... Jeypore ... ... ... ... | 50 |
| Sarangwa ... | ... 6 miles west of Desuri, Oodeypore ... ... | 34 S.W |

STEATITE.

| | | |
|---|---|---|
| Móra, Bhandári ... | ... About 12 miles north of Hindaun, Jeypore ... | 34 S.W |

The most extensive of these mines are those of Khetri and Singhana in Shaikhawáti, Daribo in Ulwar, and the lead mine at the base of the Táragarh hill near Ajmere. The rest are, comparatively, very small.

*Copper.*—That the old workings, both at Khetri and Singhana, were very extensive, and the quantity of ore raised considerable, is shown from the large and numerous heaps of slags resulting from the smelting of the copper ore. The hill on which the Singhana fort is built is formed, in a great part, of these slags.

The abandonment of the mines is attributed to the partial failure of the ore in depth and to the increased cost of working, and as the Jeypore Durbar would not reduce the royalties, the miners abandoned the mines and left the country. At present a few men make a living by picking out some stones of ore left in the old workings; and a number of people are engaged in the manufacture of Lila (blue vitriol), Pitkhera (alum), and Kasis (copperas).

The Khetri mines are situated a short distance north of the fort near the crest of a ridge of slates about 500 feet above the level of the plain. The mine is entered by several shafts of considerable depth, and which lead down to a gallery, said to be upwards of 2 miles in length. The direction of the level, as pointed out to me, appeared to be parallel to the strike of the slates. The ore now brought up from the old workings is copper pyrites; it occurs in small strings, and disseminated through the slates.

The Singhara mine is about 6 miles north of Khetri. It is entered by a wide gallery driven into a ridge of quartzite, in the same direction as the strike of the rocks, and near the top of the ridge several hundred feet above the level of the plain. This gallery is, in places, 40 to 50 yards wide and of a considerable

height. Its course into the hill is very irregular; the descent for the first hundred yards is slight; beyond this the gradient becomes steep, not less than 60°; judging from the extent of the excavation, a rich pocket of ore must have been met with. At this point three separate galleries extend into the hill somewhat oblique to each other.

Beyond the extent of the excavations very little is to be seen in these galleries, as hardly a spec of copper has been left by the old miners, and the ends are choked up by fallen debris or filled with water.

My guide through the mine had formerly leased it; and he acknowledged that the mine was abandoned from the failure of the ore in depth. But it is possible that in continuing the level southwards other pockets of ore would be met with. The mine is in a line with the Khetri mine, and it seems probable that many pockets of ore would be found if the intervening ground were explored.

Some time since, report says about a hundred years ago, the roof of the gallery for about 100 yards from the mouth fell in, and a vertical face of the quartzites has been left standing in which numerous thin strings and nests of ore are exposed.

I was told that this was the mode of occurrence of the ore in the mine. In the bottom of the gallery only a few traces of copper are to be seen, thus showing that these strings or small veins did not extend, at this place, to any depth through the quartzites.

Considerable quantities of blue vitriol (sulphate of copper), alum, and copperas (sulphate of iron), are now manufactured both at Khetri and Singhana from the decomposed slates and the refuse of the mines. The slates are steeped in water, which is afterwards evaporated in large iron vessels, when the blue vitriol is first crystallized out, afterwards the alum and lastly the copperas. Mr. Mallet found traces of nickel and cobalt in all three of these substances.

| | | | | | |
|---|---|---|---|---|---|
| The blue vitriol is sold for | ... | ... | Rs. | 14 | per maund. |
| „ alum „ | ... | ... | „ | 4 | „ |
| „ copperas „ | ... | ... | Re. | 1 | „ |

The Babai workings are in a line with these two mines and on the same band of slates, about 8 miles south of Khetri. The workings consist of a few pits sunk in the hill side. A little copper is found disseminated through the slates, but I believe the pits are principally worked for Saita, or ore of cobalt, of which mention will presently be made.

The next mine of importance is that of Daribo, near Kho, in the Ulwar territory. The mine is situated in a sharp anticlinal bend in slates and quartzites. An adit level is driven into the hill through the slates in a southerly direction parallel to the strike of the rocks. I could see no trace of a lode; the ore appears to be irregularly disseminated through the black slates, a few specs and stains only being seen in the quartzites. Where richer nests of the ore were met with, the miners have extended their workings a short distance above and below the level. The miners declare that a rich nest of ore occurs in a pit sunk below the level near its southern extremity, but it had to be abandoned on account of the water.

The present drift was, I believe, begun under the instructions of Captain Impey, formerly Political Agent at Ulwar, to drain the pits sunk by the natives in the hill side.

The copper occurs in the form of copper pyrites, mixed with arsenical iron. The mine is now nearly abandoned and but little ore is to be seen. I had some difficulty in finding a bit the size of a hazel nut.

Blue vitriol, alum, and copperas are manufactured at the mine.

I found traces of copper in some slates on the same geological horizon in the ridge a short distance west of Daribo.

The Bhangarh workings consist of two or three small pits now fallen together. The workings of Kushalgarh, Baghani, and Partábgarh have been abandoned for many years. The natives say that at the two latter places the workings were very extensive, and that the mine fell together suddenly, burying a large number of men.

A few small pits have been sunk in the quartzites west of Nabaro and west of Udhala, both near Sainthal in the Jeypore territory, from which a little copper ore may have been extracted, as the debris on the surface is stained with copper.

Near Lalsot, in Jeypore territory, a small hole has been made in the face of the scarp, and the stones about are stained with copper. At Garh, about 15 miles north-east of the above, a pit has been sunk to the depth of about 20 or 30 feet. There were traces of copper round the mouth of the pit. In both these cases, although the rocks surrounding the pits were bare and unbroken, I could find no trace of a vein or even of copper in any direction a yard from the pit's mouth.

At Nithahar, in the Bhurtpore territory, a short level has been driven into the hill and a small quantity of copper raised.

A small pit has been sunk in the quartzites about 2 miles east of Datunda in the Boondee territory. The stones are stained with copper, but I should not think sufficient was raised to pay the costs of the pit.

At Rewara, near Gangapur, in Oodeypore, a number of small pits are sunk in the schists in a north and south line for nearly a mile in length. These pits have all fallen together, or are filled with water. The copper appears to have been smelted on the spot, but judging from the small quantity of slags, no very large amount of ore was raised.

I observed traces of copper in the old iron workings near the jail at Ajmere, also at Tasing in the Mandan hills, and at Jasingpura near the railway, both in the Ulwar territory.

Captain C. J. Dixon, in a report dated 8th May 1835, published in the Journal of the Asiatic Society, Vol. IV, page 583, mentions the occurrence of copper ore at three localities near Ajmere, *viz.*, at Gúgra, 4 miles north-north-east of Ajmere, Rájgarh, 12 miles south-south-west of this, and at Rájauri, 10 miles south of Ajmere.

*Galena.*—The only lead mine of any importance occurs at the base of the Táragarh hill near Ajmere. Formerly these mines produced large quantities of lead, although there appears to be some discrepancy in the accounts as to the amount. Thus, Captain C. J. Dixon, in a paper ("Some account of the lead

mines of Ajmere") published in 1831 in Gleanings in Science, Vol., III, page 111, states: "The produce of the mines has hitherto been very limited. The annual quantity of metal smelted averages about 850 cwt.;" while it is stated in the *Ajmere Gazetteer:* "Mr. Wilder, the first Superintendent of Ajmere (in 1818), took the mines under direct management, and they produced annually from 10,000 to 12,000 maunds of lead, which was sold at Rs. 11 per maund.

"The Ajmere magazine was the chief customer, and on its ceasing to take metal in 1846 the mines were closed."

The mines consist of a number of pits sunk in a line several hundred yards long, extending from the hill to near the walls of the city. The ore occurs in a number of small roughly parallel veins running through a quartzite in nearly the same direction as the strike of the rocks. An adit level has also been driven into the hill, at a lower level, to drain these pits.

A small quantity of lead ore has been extracted from a pit sunk near Ganespura, about 30 miles south of Ajmere.

Some old lead workings occur at Indawas and Gudha, in Thana Ghazi, in the Ulwar territory. The former consists in a long open cutting from 20 to 30 feet deep, from which, apparently, a considerable quantity of ore has been raised. The workings are now filled with water. At the latter place a small pocket of ore was recently discovered, but which on being worked was found to die out in every direction.

*Iron and Manganese.*—Iron ore occurs in several localities, and some of the mines have been and are still extensively worked.

The mines of Bhangarh in Ulwar still produce large quantities of ore. These are now the only source of iron for the numerous furnaces in the Ulwar territory. The ore is a mixture of limonite, magnetite, and oxide of manganese, containing 59·67 per cent. of iron and 12·7 of manganese (Mr. Mallet's analysis).

The old and extensive mines near Rajgarh in Ulwar are not now worked.

Large quantities of a superior iron ore have been raised at Karwar, near Hindaun, but the workings are now abandoned, probably from the scarcity of fuel.

There are some old iron workings near the jail at Ajmere, but the produce must have been very small.

Iron ore is now worked to some extent near Gangar, in Oodeypore, and near Bhairompura, in Boondee.

*Nickel and Cobalt.*—Traces of nickel have been found in some of the iron ores from Bhangarh, but the pit from which the ore was taken has fallen together.

An ore of cobalt called *saita* (or *sehta*) is found in the slate hills near Babai in fine strings, and sparsely disseminated through the slates, with pyrrhotite (magnetic iron pyrites) and copper pyrites. It is described in mineralogical works as Syepoorite (probably a mistake for Jyepoorite), sulphuret of cobalt (sulphur 36·36, cobalt 64·64). The ore is used for colouring enamels, bangles, &c., of a blue colour.

*Zinc.*—Large quantities are said to have been obtained from Jawar, in Oodeypore, but as yet my examination of the country has not extended so far south as this.

*Rutile.*—Rutile (titanic acid) exists in small quantities in some little quartz veins in the Motidongri ridge a short distance south of Ulwar.

*Plumbago.*—At the back of the town of Sohna, in the Gurgaon district, a thin irregular band of schists occurs in quartzites. From these schists some specimens of plumbago have been taken. There are no traces of any excavations ever having been made, except a very small pit, which could not have been many feet deep. Anything that I could see was exceedingly poor, and hardly deserved the name of plumbago, and I doubt if any much richer was ever taken from this locality. A specimen sent to me by the Deputy Commissioner was as poor as those I picked up.

*Gold.*—When examining these schists, the Sohna Lumbadár told me that after every rains small quantities of gold were extracted from the sand, mud, &c., of the little water-courses at the bottom of the hill. I questioned the Chumárs of the town, who told me that it was true that they made a few rupees every year in this way, and that the heavier the rains, the larger the amount of gold. Last year, for instance (1877), as the rains were so slight, they did not get any, or did not think it worth while looking for.

The only rocks exposed in the gully are the quartzites and the schists. As it is not probable that the gold would be washed out of the hard quartzites, it must, I presume, come from the schists.

*Kaolin.*—The kaolin mines are situated at Kussoompur, and a short distance to south, in the Delhi hills, a few miles north of the Kutub Minár. There is only one mine now worked, and that, unfortunately, had not yet been opened for the season, so that I could only judge from surface appearances.

There are few small pits sunk in a hollow entirely surrounded by quartzites. The stuff brought out of the pits resembles, in every particular, components of the numerous granite dykes in the Arvali series, only the felspar in this case is decomposed. The plates of mica and crystals of quartz are mixed up with the kaolin in exactly the same way as they are with the white felspar in the granite veins.

This decomposed rock is thrown into water, when the mica and quartz are separated from the kaolin, and the latter made into small cakes and used for white-washing purposes, and as fire-clay.

Another kaolin mine occurs at Buchara, near the Lota river, in the Ulwar hills. There are numerous granitic veins near, and of course this kaolin is the result of the decomposition of the granite.

*Garnets.*—The Arvali schists frequently contain innumerable garnets, but it is not often that they are of sufficient size to be worth picking up. There are, however, extensive workings for them at Sarwar, 20 miles south-east of Nusseerabad, at Rájmahál in Jeypore, and at Maga in Oodeypore.

The Sarwar workings consist of a number of pits sunk in a narrow belt of mica schists, in which numerous granitic intrusions occur. The whole length (upwards of a mile) of the outcrop of the schists is burrowed in search of the garnets. Those I saw from the mine were of good colour and size, but badly cut.

The workings at Rájmahál and Maga are not quite so extensive; but they occur on the same geological horizon and were conducted in the same manner.

All of these workings are now abandoned.

*Rock crystal.*—Rock crystals were formerly obtained from some small pits sunk in the quartzites at Aurangpur, about 15 miles south of Delhi. The pits are now abandoned and fallen together, but the small crystals of quartz spread about round the pit are very numerous. Probably the rock crystal was obtained from some quartz vein running through the quartzites.

*Marble.*—Marble is of frequent occurrence among the Arvali rocks, and is extensively quarried in several places. It is generally white, but coloured marbles are occasionally met with, as at Kho and Baldeogarh, and black marble is found in the Motidongri ridge in Ulwar.

The most extensive quarries are those of Makrána, situate on the western edge of the Arvali range in Jodhpore. The marble forms a long ridge running nearly north and south. It is nearly vertical and regularly bedded; and some of the beds being upwards of 2 feet in thickness, large blocks can be obtained. The quarries are confined to about 20 feet of the section, but extend in length for several hundred yards.

Marble is also extensively quarried at Jheri, in Ulwar, and Raialo, in Jeypore.

A coarse kind of marble is quarried at Sarangwa, about 6 miles west of Desuri, on the western side of the Arvali range, in Oodeypore.

*Steatite.*—The steatite or soap-stone of which the models of the Taj and other ornamental carvings are made at Delhi and Agra is, I believe, quarried in the ridge at Mora Bhandári, about 12 miles north-west of Hindaun, in Jeypore.

## FURTHER NOTES ON THE CORRELATION OF THE GONDWÁNA FLORA WITH THAT OF THE AUSTRALIAN COAL-BEARING SYSTEM, *by* OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

In my Talchir-Karharbari flora[1] I had an opportunity to point to the greater resemblance of this flora to that in the Bacchus-marsh beds in Victoria, than to that of the New-castle beds, from the great abundance of the genus *Gangamopteris* in both, and I quoted a passage from a letter of Mr. C. S. Wilkinson, Government Geologist, to the late Rev. W. B. Clarke, which the latter had sent me for perusal, and from which it was apparent that Mr. Wilkinson assigned to our coal flora a higher position than that of the New-castle beds and lower coal-measure flora. In my notes to Mr. Clarke, which he published in his "Remarks on the sedimentary formations of New South Wales,"[2] I assigned

[1] Pal. Ind., XII— 1, p. 31, 1879.

[2] Sydney, 1878, 4th edition, pp. 163—164.

to the Bacchus-marsh sandstones a position which would bring them on about the horizon of the Hawkesbury beds in New South Wales. This seemed natural, as the Bacchus-marsh sandstones are considered as Lower Mesozoic,[1] and the Hawkesbury beds overlying the upper coal-measures or New-castle beds were treated of by the late Rev. W. B. Clarke under the heading "Mesozoic or secondary formations."[2]

I have since received several communications from Mr. C. S. Wilkinson on his observations of certain physical phenomena in the Hawkesbury beds, which would tend further to correlate these beds with the Bacchus-marsh sandstones, in which similar phenomena were observed. As Mr. Wilkinson has lately published these observations in a paper in the Journal of the Royal Society of New South Wales (December 1879), and has favoured me with a copy of the same accompanied by a letter, in which again reference is made to the Hawkesbury beds, I may, besides from this paper, quote also from his previous letters.

In a letter dated 30th September 1878, Mr. Wilkinson wrote thus:—"I have noticed certain deposits in the Hawkesbury series, apparently due to *ice action*, which would seem to confirm your view as to the correlation of that series and the Bacchus-marsh beds (in which Daintree has described the occurrence of glacial deposits) with your Talchirs. Yet it is strange that in the Hawkesbury beds we have not found the *Gangamopteris*, which is so abundant in the Bacchus-marsh and Talchir series."

The absence of *Gangamopteris* would in this case be no objection against a correlation of the Bacchus-marsh beds and Hawkesbury beds, because the correlation of the Indian Talchirs with the Ekka beds in South Africa and with the Permian Breccia in England is also based upon these similar physical phenomena only.

In a subsequent letter dated 25th October 1879, Mr. Wilkinson wrote again thus:—"Recently in company with Dr. von Haast, F.R.S., of New Zealand, I again examined the Hawkesbury beds, and the Doctor quite coincides with the views which I mentioned to you in a former letter, that these beds contain many ice-borne boulders."

In his recent letter dated 20th July of this year, he again writes with reference to the Hawkesbury beds:—"Your correlation of the Hawkesbury beds with the Bacchus-marsh beds is, I think, correct, yet it is very strange that in the former we do not find the *Gangamopteris*. This, however, may be due to the fact that in Victoria the *Gangamopteris* has only been found near the ancient margin or shore-line of the formation where the latter junctions with the Silurian, whereas our Hawkesbury fossils were obtained from beds many miles from the margin of the formation, so that the *Gangamopteris* may yet be found when searched for near the margin."

[1] McCoy: Prodr. Pal. Victoria, Decade II (*Gangamopteris*). Brough Smyth: Report of Progress, etc., 1874, p. 34.

[2] Mines and Mineral Statistics, etc., 1875, p. 181 *et seq.*

From his published note (*l. c.*) the following passages may be quoted (pages 2 and 3[1]).—"Had the boulders of soft shale been deposited in their present position by running-water alone, their form would have been rounded instead of angular. It would appear that the shale beds must have been partly disturbed by some such agency as that of moving ice, the displaced fragments of shale becoming commingled with the sand, and rolled pebbles carried along by the currents.

"From their lithological character, the Hawkesbury rocks appear to have been formed in a comparatively shallow sea which was subject to rapid and changing currents. ...... it is on the rocks near the ancient shore line that we should more especially expect to find ice-grooved pebbles, but none have yet been discovered.

"I may here remark that the sandstones and conglomerates (*Gangamopteris beds*) of Bacchus-marsh, in Victoria, have been correlated by Dr. Feistmantel with the Hawkesbury series of New South Wales. Some years ago I assisted the late Mr. Richard Daintree in making a geological survey of the district in which these conglomerates occur, and both Mr. Daintree and Mr. A. R. C. Selwyn, F.R.S., then Government Geologists, in their published reports have expressed their belief that glacial transport had been concerned in the deposition of these rocks."

From all these notes it appears evident that there are in the Bacchus-marsh beds and the Hawkesbury rocks certain physical phenomena by which these two formations may be correlated: and in the 4th edition of his Remarks on the sedimentary formations, &c.,[2] Mr. Clarke again treats of the Hawkesbury beds under the heading of "Mesozoic or secondary formation;" and in another place (*l. c.*, p. 155, Appendix XVIII) as supracarboniferous. As regards their geological position, it may be mentioned that they overlie the "upper coal-measures" or "New-castle beds" which represent the close of the palæozoic rocks in Australia.

This correlation of the Bacchus-marsh beds and Hawkesbury rocks is of no small importance with regard to our Indian coal flora; for, as mentioned before, the Talchir-Karharbári beds show the closest relation to the Bacchus-marsh beds, not only from a palæontological point of view (predominance of *Gangamopteris*), but further also from the phenomenon of "ice-borne" boulders in the Talchir and the Bacchus-marsh beds; and consequently the Hawkesbury beds would have to be placed also on the same horizon. This would have the necessary consequence that the flora of the Damuda series and that of the Australian coal-beds would differ in range, the former being *above* the Talchirs, the latter *below* the Hawkesbury beds. The case might be illustrated thus (also including the South African formations) :—

[1] This refers to the pages of the abstract, the volume of the Journal of the Royal Society, N. S. W. (Vol. XIII, 1879) in which this note is published not being yet at hand.

[2] Sydney, 1878, p. 70.

| South Africa. | | India. | Australia. Victoria. | Australia. New South Wales. |
|---|---|---|---|---|
| Jurassic beds. | Gondwana system in India, a continuous series of beds. | Upper Gondwánas (*Glossopteris*, very rare). | Upper mesozoic (Bellarine beds). | Mesozoic (Clarence river). |
| Karoo beds (*Glossopteris*, frequent). | | Panchets and Damudas (*Glossopteris* abundant in the latter). | | Wianamatta beds and |
| | | Karharbári and Talchir (*Glossopteris*, less; *Gangamopteris*, predominant). | Bacchus-marsh-beds. (*Gangamopteris*, abundant; Boulder bed, ice-action). | Hawkesbury rocks; |
| Ekka bed (Boulder bed, ice-action). | | (Talchir boulder bed, ? ice-action). | | (Boulder bed, ice-action). |
| Unconformity, break. | | Unconformity break. | Unconformity break. | Upper coal measures. (New-castle beds; *Glossopteris*, abundant). Upper marine beds. Lower coal-measures. (*Glossopteris*, first appearance). Lower marine beds. |
| | | | | Devonian. |
| | | | Silurian. | |

This list does not need any further comment. It would appear that the unconformity and break, which exists in Africa, India, and Victoria, between the Ekka beds, Talchir beds, and Bacchus-marsh beds respectively, and their underlying rocks, is in New South Wales filled in between the Hawkesbury rocks and the Devonian beds by the series of the Australian coal-bearing beds. If this surmise be correct, then an older age, than carboniferous, for the Vindhyans of India, would be an almost necessary consequence.

## Note on Reh or Alkali Soils and Saline Well waters, *by* W. Center, M.B., *Chemical Examiner, Punjab Government.*

A reference was made to this office by Government regarding the treatment of reh or saline soils by chemical manures. My predecessor, Dr. Brown, had written a report regarding the use of nitrate of lime as a remedy, and a copy of this was asked for. It could not be found in the records of the office, but I afterwards found that it had been published in the Selections from the Records of the Office of the Financial Commissioner, and the gist of it was embodied in Powell's book on Punjab Products. As I had made numerous analyses of such efflorescences, and studied their connection with saline well waters, samples of which I had analysed from all parts of the Punjab, and as I had an opportunity of observing and learning something of similar soils known as alkali soils in the Utah

Basin and other parts of America, and of the methods used to reclaim them, I beg to submit a few notes on my observations. I am indebted to Captain Ottley, of the Irrigation Department, and Mr. Miller, Secretary to the Financial Commissioner, for access to the literature on the subject in the form of reports to Government. I propose considering more especially the chemistry of the production of those salts and the conditions of their accumulation in soils and in the underground water,—points intimately connected with each other, and equally important in the agricultural and sanitary aspects. The efflorescences consist chiefly of sodium chloride and sulphate in varying proportions. In addition there is sometimes carbonate of soda, and I have usually found some magnesian sulphate. In certain localities the last-named salt is in very considerable proportion. In other cases nitrate of lime or alkali is present.

Marine theory.

2. Various theories have been started regarding the origin of these efflorescences, the oldest being probably the marine theory. According to this the Indo-Gangetic depression was considered to be an old sea bed, the soil of which became impregnated with salts from the existence of shallow "rans" and lagoons in a former geological age. In favour of this it might be mentioned that there is certain geological evidence that an Eocene sea covered the Punjab plain, its shore coinciding with some part of the outer slope of the Himalaya, with a gulf or gulfs penetrating the mountains as far as the valley of the Upper Indus. On the other hand, to the east of Kumaun and to the north of the Gangetic valley, the situation of this shore line is obscured till the Assam region is reached. The theory of recent marine impregnation is now entirely to be abandoned. It is proved beyond doubt that the whole of the materials of the Indo-Gangetic basin are fresh water alluvia to an unknown depth, and consist in fact of the debris of the Himalayas carried down by its drainage and deposited in this immense depression. There are no deep natural sections in which to observe the structure, but in the Umballa boring of 701 feet, the Calcutta boring of 481 feet, and that near Rajanpur of 464 feet, nothing but fresh-water alluvia were met. We do not speak here of the Salt Range region, in which are accumulations of salt as old as the Silurian period.

True origin of reh.

3. The true origin of reh or alkali efflorescence is the decomposition of the elements of rocks and soils which is continually going on under the action of air and water. The accumulation of the resulting salts in superficial soils or in subsoil waters depends on various conditions of chemical constitutions and permeability of soils, and on the nature of the surface and subsoil drainage, which will be considered in detail.

Decomposition in hill regions.

4. If the rain water that runs off the surface of the hills be examined, it is found to have washed out appreciable amounts of soluble salts, chiefly carbonate of lime and alkaline chloride and sulphate. If such water runs off crystalline or schistose rocks, the amount of salts washed out may be extremely small,—even 2 grains per gallon, as at Dalhousie. If it runs off a loose decomposing rock the quantity may be considerable,—for example, 8 grains near Murree. The rainfall that percolates the debris of the decomposed rock which covers the surface of the hill-sides and fills up the channels of ravines issues in springs at lower levels, and is found to contain

much greater proportions of the same salts. This water not only comes in contact with a larger quantity of degraded rock and washes out its soluble salts, but it takes up more carbonic acid from the air in the pores of the ground, which is rich in this gas, and this dissolves more lime and magnesian carbonate. From 10 to 25 grains per gallon are found in springs in clean soils in various hill stations. In the hill stations themselves, where the porous subsoil becomes loaded with sewage impurity from human habitation, the dissolved salts and organic impurity may be very great. For example, in the bazar well at Murree I found 35 grains per gallon in which were 12 grains of common salt. This last is, however, a sanitary fact, and I wish at present to speak generally of the saline ingredients washed out of such soils not contaminated by human occupation.

5. The soluble substances produced by rock decomposition and dissolved by water are remarkably uniform in their nature, though varying in amounts, both relative and total, according to the nature of the decomposing rock or soil. It may be generally stated that the earth water shows a fugitive acidity from the presence of free carbonic acid and a slight permanent alkalinity from the presence of alkaline carbonate, but that the main ingredients are carbonates of alkaline earths, chiefly of lime, and alkaline chlorides and sulphates, chiefly of soda. Other ingredients are generally in smaller amount, such as lime and magnesian chlorides or sulphates forming the permanent hardness, also silica, traces of iron, &c. Of course in special formations it may be highly charged with peculiar salts, and may even form what are called mineral springs; but we are speaking generally of the body of water that filters from the hill-sides, and either sinks into the underground strata of the plains or finds its way into the streams and rivers, and thence into the sea, the great natural reservoir of the soluble salts washed out of the earth. The waters of the Punjab rivers which I have examined, the Ravi, Jhelum, and Indus, contain 8 to 15 grains per gallon, varying according to the floods. The amount of soluble salt capable of efflorescence varies from about 2 to $4\frac{1}{2}$ grains. The river waters are most concentrated when they are at the lowest. At that time they are supplied by the water that has filtered through the soil and subsoil of the higher regions, and has thus taken up more salts. In the hot weather, when the glacial water comes down, and in the rain floods at the end of the hot season, the dilution is at its highest. Other glacial rivers and those subject to annual floods show the same thing. For example, the total solids in Nile water vary from $9\frac{1}{2}$ to $14\frac{1}{2}$ grains per gallon.

Ultimate origin of reh salts.

6. To explain the ultimate origin of these salts we have to consider the action of the oxygen and carbonic acid in rain water on the rock elements. With the exception of the limestone strata, which consist of carbonate of lime, often with carbonate of magnesia, all great rock formations are composed of silica and silicates, chiefly of alumina, lime, magnesia, soda, and potash, with smaller amounts of iron and other metals. Such is the constitution of the granites, gneisses, slates, traps, &c. The old sedimentary rocks are similar in composition, being formed by the disintegration of these. The recent alluvia of the plains consist of finely-divided debris of the limestone and silicious groups, and in them the chemical decomposition going on under the influence of air and water is much intensified, owing to the state of fine division

which favours chemical action, and because the constituents of the soil are further advanced in the path of degradation.

Origin of carbonate of lime alkaline carbonate.

7. In order to understand the slow chemistry going on in the ground, we have to conceive the outer shell of the earth generally covered with more or less vegetable mould, and permeated to its greatest known depth by meteoric water. There is no rock, however compact, and there is no depth to which man has penetrated, in which water is not found to have permeated by pores, cracks, or fissures. The great agent of change is the carbonic acid of the air. This is dissolved in rain water, which also dissolves more from the decaying vegetable mould and from the air in the pores of the ground, which is rich in this gas. It has two great functions. It attacks the silicates of the alkalis and lime, forming carbonates. It further dissolves the carbonate of lime, enabling it to be transported by water and to be redeposited on evaporation. From the limestone rocks the water takes up carbonate of lime and magnesia, which dissolve in its free carbonic acid, and in such formations it becomes very hard. The amount of carbonate of magnesia dissolved is always much less than that of lime. In the silicious rocks the felspathic family of minerals decomposes most readily. These consist of silicates of alumina and alkali, with generally small quantities of lime and magnesia. The white or soda felspar, which contains more soda than potash, is a common ingredient of the Himalayan rocks, and the decomposition of this in soils may possibly to some extent account for the very great excess of soda over potash salts. The chief reason, however, depends on the fact which has been experimentally verified, that in a silicate containing both potash and soda the latter is dissolved out with greater facility and in much larger quantity than the former. The process of decomposition consists in removal of the alkali by the action of carbonic acid, while water is taken up, leaving hydrous silicate of alumina or clay. The presence of alkaline water also assists in promoting the breaking up by dissolving some silica. Another group, the lime silicates, is also readily decomposed by the action of carbonic acid or alkaline carbonate, and forms an additional source of carbonate of lime. On the other hand, the talcose rocks, which contain magnesian silicate, are hardly attacked at all. This magnesian metamorphosis of rock, which is very extensive and very ancient, is also the most permanent, and apparently a final one. We have thus accounted for the alkaline carbonate and carbonate of lime. The earth water is almost always slightly alkaline, and this plays a most important part in the decomposition of the silicious rocks and their metamorphosis. The alkaline carbonate rarely, however, appears in large amount, because it partly expends itself in decomposing silicate of lime, thus forming carbonate of lime, and if free carbonic acid is present, this will be dissolved and carried away by the water. If magnesian or lime sulphate be present, the carbonate of soda with these will produce lime or magnesian carbonate; while sulphate of soda will be found in the solution. It thus happens that the waters of the rivers contain apparently no alkaline carbonate, but show a permanent neutral re-action. All the river waters, in addition to carbonate of lime, which is their chief ingredient, contain also lime and magnesian sulphates which there has not been enough alkaline carbonate to decompose.

8. The circulation of the sulphur that occurs in the earth is very interesting.

Origin of sulphates.

That which forms the sulphates in the earth-water appears to be derived from the sulphurets, especially of iron, which are so universally diffused in rocks, and from the gypsum rocks, which, however, form an insignificant portion of the strata. The sulphate of lime being moderately soluble may be readily taken up by water. The sulphurets become oxidised by the oxygen in air or water, leaving red iron oxide, which gives the yellow or red colour to soils and clays; while the sulphuric acid attacks the silicates and unites with soda or lime. In the strata of the earth are found deposits of sulphates of lime, but these appear to have been deposited from solution by infiltration, or by evaporation, as in the Salt Range. Their ultimate origin is probably the same as that just indicated. The presence of sulphate of lime in soils leads to the production of sulphate of soda. The former salt is slightly soluble, and as the earth-water contains alkaline carbonate, mutual decomposition leads to the formation of carbonate of lime and sulphate of soda. This partly accounts for the excessive proportions of sulphate of soda often found in reh. The sulphates may be again reduced to sulphides by organic matter from the vegetable mould or other sources, which accounts for the presence of sulphuretted hydrogen in dirty well waters rich in sulphates.

9. As regards the chlorine of the alkaline chlorides, there is more difficulty.

Origin of chlorides.

Chlorine is not an important chemical constituent of any common minerals forming rocks, but there is no rock that on being powdered and washed with distilled water does not show its presence. The only explanation known of its appearance lies in the fact that, though generally in minute quantities, it is the most universally diffused substance we know. Even in air a chemically clean platinum wire cannot be exposed for some time without showing the sodium line in the spectroscope due to sodium chloride which can be extracted from the air dust.

10. There is next to be considered the chemistry going on in the decomposi-

Formation of salts in the plains.

tion of the debris of the rocks forming the plain. It is in a more finely-divided state, and is therefore in a condition more favourable for chemical action, and besides the constituents are in a further advanced state of decomposition than in the fresh rocks. The action that has been described is therefore intensified. It has been proved by experiment that it is from the most finely-divided clay (felspathic) particles of soils that most of the soluble substances can be extracted. These particles are so extremely fine that under the microscope they are seen only as minute dots. The other small particles which are of measurable dimensions are silicious, and yield to acids only a slight amount of soluble matter.

11. There are three points to be considered,—the action that takes place on the surface, that which takes place in the strata permeated by the underground water, and also the relations between the two.

12. On the surface undoubtedly the greatest amount of decomposition goes on

Surface production of salts.

from the united action of air, moisture, heat, and light. This produces the perennial supply of soluble salt necessary for the growth of plants, and in cultivation it is assisted by turning up and

pulverising the soil and acting on it by water. In countries with good surface and underground drainage there is a constant escape of these salts, and the difficulty may be how to get enough of them. In many parts of our plains circumstances favour their accumulation, and the question is how to get rid of the excess. I have frequently taken samples of soil and subsoil from places where there were efflorescences and where there were none, and on washing out the soluble substances with boiled distilled water found that they were similar, but different in amounts. They always consisted chiefly of alkaline chloride and sulphate, with often small quantities of alkaline carbonate, and frequently larger amounts of soluble magnesian salt, sulphate or chloride. Another experiment was to take a sample of reh soil and wash it repeatedly till no trace of soluble salts could be found. It was then dried and thoroughly mixed and a portion tested again to see that no soluble salt was present. It was then placed on a filter and covered with porous filter paper so as to exclude dust, but allow evaporation, and the bottom of the glass filter was corked. It was frequently watered with distilled water charged with carbonic acid and exposed to the heat and light of the sun in the hot weather for nearly three months. At the end of that time it showed no efflorescence, but on being washed with distilled water the solution showed the presence of considerable quantities of alkaline chlorides and sulphates. This experiment proved that in that species of soil a sensible production of reh salt may take place in a few months. A similar sample irrigated with ordinary well water rapidly developed an efflorescence owing to the presence of salts in the water. There is nothing particularly novel in these results. Experiments have often been made of grinding down the solid rock from the debris of which the adjoining country was formed. On washing out the powdered rock the solutions were found to contain the salts of the water of the district; indeed it is always possible to account for the composition and proportions of the ingredients in a water draining any area if the structure and composition of the rocks are known.

Approximate estimate of decomposition in soils: the Lysimeter.

13. To estimate approximately the decomposability of a soil, the simplest method is to dry and weigh a sample and wash out from it the soluble salt already present. On drying and weighing the residue and deducting its weight from the original there will be found the soluble salt (along with some organic matter). This is the result of decomposition already accomplished. The solution may be tested in the usual way, by evaporation to find the total dissolved matter, and by ignition to find organic matter. The washed residue of earth is then ignited to expel all remaining organic matter, and treated with hydrochloric acid, which will decompose and dissolve the materials which are in an easily decomposable state. The solution will contain lime, magnesia, alumina, and iron, and also the alkaline bases capable of efflorescing. On deducting the undissolved residue from the former, a figure will be found, which will be an approximate index of the facility of decomposition of the soil. The hydrochloric acid solution can be examined in the usual way if required by first precipitating the iron, alumina, and phosphates of the alkaline earths, then the lime, and afterwards separating the magnesian and alkaline bases. The last will show the salt capable of efflorescing. A more

correct way is to perform an experiment similar to what I have described before with the glass funnel. A zinc box is made open at the top and closed at the bottom, with a false bottom of perforated zinc half way down. The section is usually 1 square foot. Earth is placed above the perforated zinc, and the whole is exposed to the varying conditions of the season and climate, as rainfall, heat, moisture, &c. All water that falls sinks through the perforated bottom, and is collected or evaporates. After some months or a season the solution in the bottom of the box and the earth are examined in the usual way to find the results of decomposition. Such an instrument is called a Lysimeter, and has the advantage of demonstrating the changes that take place, not by the action of acids, but by the ordinary operations of nature.

Underground production of salts.

14. Another source of generation and accumulation of these salts takes place in the strata moistened by the underground water. This is partly derived from percolation of rainfall from the surface where it is sufficiently porous. In its passage downwards it washes out any soluble salts it meets and carries them down till it reaches the impermeable stratum. In the second place the air contained in the vegetable mould and porous ground is rich in carbonic acid, and this is absorbed by the water and enables it to dissolve more lime and magnesian carbonate, which accounts for the much greater hardness of subsoil waters. In the third place the alkaline water charged with carbonic acid not only promotes the decomposition of the strata through which it filters, but by a constant soakage action on that which it moistens produces still more. The amount produced would be in a great measure proportional to the time the water remains in contact with the stratum. In stagnant underground waters in the middle of the plains, as at Chunga Manga and Wanradaram, the dissolved salts amount to 400 grains per gallon. Another feeder of the underground water is the percolation of hill water that sinks into the porous fringe at the base of the hills. This, however, affects particularly the plain near the base of the hills. The solution formed from the debris on the hillside is much less saline than that from the finely-divided and more degraded materials of the plain. The hill percolation therefore affects the underground water near the hills in two ways. It raises its level by hydrostatic pressure and it makes it less saline by dilution. There is still another source of underground waters in the percolation from rivers, streams, and canals. The neighbourhood of rivers affects the water-level, and very sensibly influences the quality of the subsoil water. Analyses of waters taken from wells near them show that they closely approximate to the river waters, being little more than those filtered. For example, the well water near the Ravi was found to contain from 8 to 15 grains per gallon, that near the Jumna 9·8 to 14 grains. Advantage is now being taken of this in supplying water from such wells to some large cities in the Punjab. The influence on the quality of the subsoil water, however, only exists in the khadar land, or low river valley. In the bhangar, or bar land, the upland that lies between neighbouring rivers, even at short distances from the valley, the water may be highly saline. In the case of canals, as far as my observation goes, there is very little percolation in the districts I have seen irrigated by the Bari Doab Canal, on account both of the impermeability of the soil and

the disposition of the strata. If, however, a canal were made on a natural line of drainage, as I have heard the Western Jumna Canal is, it might influence the adjoining ground in the way I have mentioned in the case of rivers, both as to the water-level and quality of percolating water.

Nature of reh and its varieties.

15. When rain water sinks into a soil containing soluble salts, it dissolves them and carries them down till it reaches an impermeable stratum. Medlicott has pointed out the action of the first rain drops in carrying efflorescent salts down, so as to be in a great measure out of the reach of the surface scour of the succeeding rainfall. If the soil is porous, it may gravitate down to the water stratum, which then becomes a reservoir of the surface salts. If it is only slightly porous, as in alluvial soils containing much clay, the soakage is only superficial to one or more feet in depth, and generally in such cases the surface soil is more or less porous from atmospheric exposure, and below it lies a more compact clay subsoil. As rain water contains free carbonic acid, it dissolves also carbonate of lime and magnesia if these be present in the soil. When evaporation succeeds, it draws up the moisture in the more porous surface soil by capillary action. As the water and carbonic acid pass off, the solution becomes more concentrated and carbonate of lime is redeposited. This last action takes place first, and as the concentrated solution is drawn up to the surface, it finally deposits its most soluble salts on drying as an efflorescence on the surface. An essential condition is the dryness of the climate. In more temperate, but dry regions, as in the Utah Basin and the elevated parks or plateaus of the rocky mountains, efflorescences appear as well as in the scorching plains of India. The action, however, is intensified by heat, which increases evaporation. By similar capillary action the moisture will creep up the sides of objects lying on the ground, such as pieces of brick, and deposit a copious efflorescence. At first it appears in glittering crystals, but as the sodium sulphate gradually loses its water of crystallization, it breaks up into a copious white powder of anhydrous salt, and it is then that it is most apparent. The carbonate of soda behaves similarly, but the sodium chloride does not, having no water of crystallization. Nitrate of soda and lime deliquesce in damp air. During the hot months, the salts, if brought up by rain, melt in their water of crystallization. By the word efflorescence we do not mean here what is known as such in chemical language, that is, the breaking up of a crystallized salt into a powder from loss of water of crystallization. What is meant is efflorescence in the physical sense, or the appearance on the surface of the ground of soluble salts brought up by capillary evaporation. It is true that sulphate and carbonate of soda effloresce in the chemical sense, but chlorides and nitrates do not.

16. From what has been explained regarding the origin of the salts dissolved out of the earth, it can be understood how the solutions can naturally be divided into two groups, whether they be river and canal waters, or well waters, or solutions formed when rain water soaks a saline soil. There are first the neutral solutions from which carbonate of soda has almost or entirely disappeared, having been used up in decomposing any soluble lime or magnesian sulphate or chloride and precipitating their carbonates. To this belong the river and canal waters, the chief ingredient of which is carbonate of lime with less amounts of

magnesian carbonate held in solution by free carbonic acid. There is present probably next in amount soluble salt of lime and magnesia, sulphate or chloride—the magnesia in smaller amount. The alkaline chloride, though the most constant ingredient in all waters, is in small amount, from ½ grain to 2 grains, and the alkaline sulphate in about equal or larger quantity. In the majority of well waters in the plains in my experience there is high permanent hardness, indicating lime or magnesian sulphate or chloride, and sodium carbonate is deficient. The total dissolved salts is in fresh well waters about double that in rivers and canals, and may rise in saline wells from 10 to 40 times the amounts, the increase being chiefly in carbonate of lime and alkaline chlorides and sulphates.[1] The second group of waters or solutions is that containing carbonate of soda. In these there is generally little permanent hardness, or soluble lime or magnesian salt. If these two groups on evaporating produce efflorescence, in the first we may have sodium chloride and sulphate, and any magnesian sulphate, if present; in the second we may have sodium carbonate with sodium sulphate and chloride, but no lime or magnesian salt. During the process of drying, which leads to the efflorescence, the first thing that occurs is the deposition of lime and magnesian carbonate, as the free carbonic acid disappears. Subsequently, sulphate of lime being only little soluble would deposit, and the highly soluble salts, including sodium carbonate, chloride and sulphate, magnesium and calcium chloride and nitrate and magnesium sulphate, would be capable of efflorescence. These salts, however, are not deposited as they exist in solution, as new laws come into play. The chief of these is, that during evaporation the least soluble salt that can be formed is first deposited; but this is modified by two other laws, the tendency of certain compounds to form double salts, and the tendency of substances with the same crystalline form to crystallize out together. The efflorescences thus produced consist of three groups; 1*st*, the neutral, containing no carbonate of soda, consist chiefly of sodium chloride and sulphate, and frequently magnesium sulphate; 2*nd*, the alkaline, containing carbonate of soda and alkaline chlorides and sulphates, but no lime or magnesian salt; 3*rd*, the nitrous efflorescences. These generally contain no alkaline carbonate, and consists chiefly of nitrate of lime and alkaline chlorides. Others contain alkaline nitrate, chloride, and sulphate. They are developed where the soil has become loaded with organic nitrogenous matter. In several places about Lahore there is a good deal of magnesian sulphate, and I have observed on twigs of farash trees a saline coating of this salt. Reh is thus not a special salt or mixture of salts, but a very variable compound. It is really the most easily soluble salt in the earth-water, remaining in solution after the deposition of carbonate of lime, &c., on evaporation. The ingredients and their relative proportions are found to vary in different places, exactly as the well waters at different spots differ in saline contents, and in the same area there is a

[1] Though we speak usually of individual salts existing in a solution, this is not, strictly speaking, scientifically correct. If, for example, sodium chloride and lime sulphate be made into a solution, it will really contain quantities also of sodium sulphate and lime chloride, and the amounts of the four salts will depend on the masses of the first two, temperature, concentration, &c. Properly speaking, in recording an analysis, the total amount of acids and bases should be separately recorded. By a conventional rule, however, it is customary to arrange the salts hypothetically.

close relation between the two. The relative proportion of common salt to sodium sulphate was found by Medlicott to vary from 4 to 24 per cent.

Formation of kankar.

17. The re-deposit of carbonate of lime gives rise to those nodules known as kankar. It takes place at the upper margin of the impermeable subsoil. They are not formed by the lime depositing round a nucleus and pushing the other elements of the soil aside. A portion of rather porous soil, consisting of a mixture of lime, sand, and clay, is infiltrated with water retained in it by an impermeable bottom. The carbonate of lime is deposited throughout this porous mass, and cements its particles together till it becomes of a stony hardness. Deposit no doubt also takes place along the outer surface, as each former minute crystal deposited acts as a nucleus for further deposit. The formation is often seen in an incomplete state, nodules of soil having become only partially hardened. The process is essentially one of segregation from the soil itself. Such nodular formations, which are very common with other minerals, as iron oxide, silica, &c., are an example of the simplest kind of metamorphosis going on in rocks and soils. It is not necessarily connected with efflorescences on the surface. The essential condition of its existence is the presence of carbonate of lime, or its ready production by ordinary decomposition in the soil. In soils and sub-soils which supply little lime there may be efflorescences without formation of kankar, as in those consisting of clay and silicious sand. On the other hand, in marly soils, in which there may be little production of alkaline salt, kankar may form without any efflorescence. The analysis of kankar very well illustrates their mode of formation. They show from 20 to 50 per cent. of carbonate of lime, the rest consisting of the mixture of clay and sand of which the soil is composed.

Estimation of reh in soils and water.

18. To estimate practically the amount of injurious reh in any soil, it should be washed with boiled distilled water and the solution evaporated, then burned to expel organic matter and finally weighed. In the case of the waters of rivers, canals, and wells, they should be evaporated, ignited, re-carbonated, and weighed. The easily soluble salts should then be washed out with a little distilled water and the residue weighed. The portion undissolved consists of lime and magnesian carbonates and some sulphate of lime with small amounts of silica, &c. The difference between the two weights is the amount of salt capable of efflorescing. If one have a record of the analysis of any water, a rough approximation is got by deducting from the total solids the volatile matter (almost all organic), also the removable hardness consisting of carbonate of lime. In addition two grains per gallon of carbonate of lime should be further deducted, as in boiling (in order to remove carbonate of lime), two grains per gallon still remain dissolved. A still further deduction would require to be made for silica, iron, &c., but these are in small amount. I mention these methods of approximate estimation because they are readily applied and are useful for all practical purposes.

Causes of accumulation of salts.

19. In considering the conditions that lead to accumulation of salts on the surface or in the underground water, it is to be borne in mind that soils exposed to moisture, air, and heat are continually generating them, and that in some in which the felspathic elements

are undergoing rapid decay the production may be profuse. Also all water, river, canal, or underground, that has washed over or filtered through the ground, contains similar salts and promotes their further production.

Accumulation in basins.

20. The simplest case of accumulation is that of a closed basin like the Utah Basin. The surface water washing the salts off the ground has no escape to the sea, and forms an inland salt lake. The soil in such cases is very saline, except in places where there is slope to allow thorough surface washing by rainfall, or permeability to allow the surface salt to be washed down to a deep ground water. In the centre of the depression both the surface and sub-soil and the sub-soil water are loaded with salt. The efflorescences in Utah closely resemble those in the Punjab, the main common ingredients being sulphate of soda, common salt, and often sulphate of magnesia. In some places there is a large amount of carbonate of soda, in others borax is present. In the Caspian Basin the main ingredients are sulphate of soda and common salt. The very opposite case is a hilly or undulating country with sufficient rainfall and good natural surface drainage, the strata of which are also inclined, thus allowing of natural sub-soil drainage till the underground water finds an outlet at the outcrops of the strata, or where they are laid open by natural sections of the country. Here the salts continually formed are either washed off the surface or are carried down to the sub-soil water which drains them off.

Accumulation in plains.

21. In examining the state of things in the Indo-Gangetic plain, it is necessary to consider the structure of the country. The Himalayan axes stretching along the north of the plain are elevated cores of granitic gneiss flanked by metamorphic and limestone rocks. To the south of this is the Siwalik-fringe with its dúns, consisting of clays, sandstones, and conglomerates. These are fresh-water deposits formed by river and torrent action in the tertiary period, and having suffered displacement by the Himalayan elevation, they are seen to pass with great undulations and numerous fractures under the strata of the plain. This formation conducts water under the plain. There succeeds to this the recent gravel deposits from the outer hills, brought down by river and torrent action, similar to that which caused the Upper Siwaliks, and known as the Bhábar. This is extremely porous, and a great part of the water of the streams passing over it sinks into the ground and issues in springs at a lower level in the adjoining part of the plain, which is known as the Terai. Part also sinks beneath the plain and raises the groundwater level. The great alluvial plain itself is composed of horizontal strata. Near the hills are gravel deposits, but further off the soil and sub-soil to an unknown depth are composed of deposits of clay, sand, and mixtures of the two in various proportions, according to the stream or lake action that deposited them. Diffused through these are found mica and small quantities of carbonate of lime, which makes soils more or less marly, and iron oxide which gives them a yellow or red colour, and minuter amounts of sulphate of lime and other salts. From numerous well sections it is seen that these alternating permeable and impermeable beds of sand and clay are not continuous, but that they thin out and are replaced horizontally by others. This is observed even at

short distances. Possibly many of the sheets of clay may have more or less of a basin form. The important points for us to remark in considering the surface and sub-soil drainage are that this immense plain has an average breadth of about 200 miles, that practically the Gangetic and Punjab plains are one, the water-shed between the two being only perceptible by accurate scientific measurements, and that its length is about 1,200 miles. There are also no deep natural sections exposing outcrops of the deep strata so as to allow of escape of underground water to the sea. In consequence of the very small surface slope, and on account of the horizontal disposition of the strata over such an enormous area, the conditions as regards drainage approach to those of a basin. The surface drainage is weak, but ultimately finds its way by the rivers to the sea, but the underground drainage is usually imperceptible.

22. As regards the production of efflorescences, we have further to consider that in the Punjab there are three belts of plain. That adjoining the hills, the sub-montane tract, has a plentiful rainfall and moister air; south of this is a sub-desert tract with small rainfall, and still further south is the desert country with deficient rainfall. In the sub-montane belt the rainfall is sufficient to scour the surface, and as it is more permeable from the presence of gravel and sand, and has greater slope, the surface and subsoil drainage are more efficient. In the other two tracts the working of these agencies is defective. In the hills themselves the annual rainfall of a series of years is as follows: Murree, 56·8 inches; Dharmsala, 123·2 inches; Simla, 68·6 inches. This does not include snowfall however. In the sub-montane belt we would have—Rawalpindi, 32 inches; Sialkot, 39·3 inches; Gurdaspur, 33·1 inch; Hoshiarpur, 36·5. Of the less-watered region there is Lahore, with 19·3 inches; Shahpur, 14·5 inches; Sirsa, 14·5 inches; while about Mooltan the rainfall is 6·9 and at Dera Ismail Khan 8·2.

23. The simplest case to consider is that which occurs in the more desert country, in which the rainfall is only enough to moisten the surface and promote decomposition. If the soil is sandy the dissolved salt is carried down to the underground water and the accumulation takes place there. If the ground is not porous, as where clay predominates, only the upper portion is soaked, and on drying the soluble salts are brought to the surface. Instances of both these cases are found everywhere along the southern portion of the Punjab plain. In the middle portion of the plain, where the rainfall may go up to 20 inches, similar actions take place. The first drops of rainfall dissolve any efflorescence and sink into the ground, carrying it out of the reach of surface scour, which on account of the flatness of the plains and small rainfall is slight. In the more porous portions the salt is carried down to the underground water; in the more impermeable it is brought to the surface by evaporation. It thus happens that in certain places there is a scum of efflorescence on the surface, while generally the ground water is saline. These remarks apply to the Doab or Bhangar land, the more elevated part of the plain lying between adjacent rivers. In this the water lies at a considerable depth, from 30 to 100 or more feet, and is more or less saline; in many places on digging deeper to another stratum fresher water is found. In the other great plains of the earth where the climate is dry

and like conditions of soil prevail, similar efflorescences are developed. In the dry pampas of South America they consist chiefly of sodium sulphate with some common salt; in the Siberian steppes, of sulphate of magnesia along with sulphate of soda and common salt. They are likewise found in the Russian steppes and the Tibetan plateaus.

24. The Khadar, or low-lying river valley, cut out by recent erosion from the old alluvial plain, usually shows little or no saline accumulation on the surface and none in the underground water. Here the circumstances are all different. In fact the river occupies the line of natural drainage of the country, and its deposits are parallel to the line of slope. Accordingly, the water percolating from the river forms a subterranean stream, gravitating down the river-course and accompanying the main stream. Its extent depends on the permeability and arrangement of the strata and the resistance of the porous beds along which it moves. In the beds of dry nullahs this gravitating water may be met on digging in the dry channels. If the underground water were stagnant, remaining long in soakage contact with the water-bed, it would become more or less saline, whereas it is found to resemble the river water filtered, though of course it has taken up some ingredients from the earth, chiefly more carbonate of lime. In two cases in which I examined the water in beds of dry nullahs, I found it much less saline than that of the surrounding plain. In the Khadar land the water lies near the surface, and may be within the reach of capillary evaporation, which would produce efflorescences, as it often does to some extent. But in consequence of the occasional washing by floods, and of the underground circulation I have described, there is no permanent accumulation either on the surface or in the ground-water.

Accumulation by evaporation from a shallow water table.

25. One of the most interesting and important cases is that in which the ground water lies close to the surface within the reach of capillary evaporation, thus furnishing an unlimited supply of efflorescence. The enquiry made by the Aligarh Committee chiefly referred to this instance. It was considered that the ground-water level had been raised by percolation from the canal, assisted by hydrostatic pressure, in consequence of the canal being above the level of the country. Other causes assigned for the rise were the obstruction to surface drainage by canal and railway embankments acting as bunds, and the practice of profuse irrigation in flooding. All these would lead to an increased body of water sinking into the ground, carrying earth salts in solution to be again brought up by capillary evaporation from the shallow water table. It is very important to be able to estimate how much is due to each of these agencies, as on the decision of this point would depend the remedial measures to be applied, such as the lowering the level of the canals, their realignment on the high Bhangar land instead of on the lower ground, the restriction of profuse irrigation, the relieving of the surface drainage, and the establishment of artificial sub-soil drainage. I am unable to enter into the merits of these most interesting points because I have never had an opportunity of making observations on an area where this mode of generation of reh was going on to a serious extent. The only portions of country I have seen in which the ground-water lies very near

the surface are the plains adjoining the hills and the Khadar lands or river valleys. In the former the rainfall is more plentiful, the slope of the surface and deep strata are better, there is more moisture in the air, and therefore less evaporation. All these tend to prevent accumulation of salt below and efflorescence above. In the latter the washing of the surface by the floods and better subterranean drainage may account for the want of accumulation. In the parts of the Bari Doab Canal which I have seen, the ground-water lies at a depth that is totally out of the range of capillary action, and the strata consisting of alternating clays and sands are so impenetrable that percolation can have little effect on the water level. Captain Ottley informs me that on the Bari Doab and Upper Sutlej Inundation Canals the curves of the rise and fall of the well waters markedly follow those of the rainfall and do not appear to be affected by irrigation. I did not find any marked difference in the water levels of the wells near and at a distance from the canal about Lahore. A still better proof was that the salinity of the wells was not altered by proximity to the canal. If percolation to any extent existed, the wells close to the canal ought to be fresher than those at a distance. In the part of Lahore occupied by the railway station and barracks the ground-water is salt. At the end of the hot weather I found that a well a few yards from the canal contained as much salt as others far off. After the rains the same well waters were found to be so diluted as to contain less than one-half of the former amounts. The depth from which capillary evaporation can take place is also a question that ought to be investigated by observation and experiment. Much of course depends on the porosity of the soil, but in the most favourable cases one would fancy, from the known laws of capillary force, that the action would only be through a few feet, unless assisted by hydrostatic pressure. At the village of Baoli, on the Western Jumna Canal, where the reh action is very pronounced, the depth from the surface of the ground to the water table (as shown by measurements of an unused well) is 8 feet. It is said that before the Western Jumna Canal was re-opened in 1819, the water in wells about the part lay at a depth of 60 to 70 cubits, and this tradition appears to be confirmed by inspection of the records of other wells which had been sunk to as much as 116 feet, and in which now there are 62 feet of water. On the banks of water-courses and canals about Lahore in salt soils one often observes two lines of efflorescence, one a few feet above the water level at the upper limit of capillary soakage, and another some distance from the surface, at the base of the surface percolation. As regards the rise in the well water levels said to be caused by canals, it would be necessary to have accurate information as to what those levels were before the canals were made. Probably no accurate record was made before the earlier canals were started, as attention was not directed to the point.

**Other modes of accumulation.**

26. There are last to be noticed some other modes of distribution and accumulation of alkali salts. Irrigation by flooding and allowing the water to dry on the soil, unless it is very permeable, of necessity leads to production of salt. Not only does the irrigating water contain salt which it deposits as an efflorescence, but it also promotes further decomposition in the soil. The amount of reh in ordinary canal water

might be from 2 to 6 grains per gallon. If well water is used, the accumulation is much greater, because it contains much more salt. In places where the water is sweet, the reh may be about 6 to 15 grains per gallon; where it is salt, it may amount to more than 200 grains per gallon, as at various places on the Railway Line between Lahore and Mooltan. An extraordinary instance is mentioned in the Aligarh Report of a reh soil tried by the most energetic measures without effect. An analysis of this soil would probably have proved that the elements of the soil itself were in such a state of decomposition that most of the measures employed assisted the process. Again, water running off a saline field must necessarily dissolve a portion of its salt, and if it be allowed to run into another and dry, that salt will be deposited. The agency of wind appears to be a slight and very variable one. There is no doubt that wind blowing over a saline country and raising dust transports saline particles. Travellers over the alkali plateaus of the Rocky Mountains are familiar with the irritation caused to the eyes by this mode of transport. All these, however, are of secondary importance. The main points to bear in mind are, that there are several factors causing production and accumulation, and others leading to the removal of earth salts. Of the former there is first the soil itself. This is always generating them, and in certain cases its materials so readily undergo decomposition that perhaps even artificial means may fail to cure the evil. The next chief factor is the water used in irrigation. This always contains reh salts,—the river and canal water in small amount, but the well water often in enormous quantities. In addition, the irrigation water may not only deposit its salt in the soil, but it causes further production in the soil itself. Another cause is the special condition in which the subsoil water lies within the reach of capillary action from the surface, which may give rise to an inexhaustible supply. The factors concerned in the removal are, first, permeability of the soil, which may allow the salts to be washed down to the underground water. If this have a ready outlet, they are removed; if not, there will be a saline ground water; but the surface may show no accumulation if the water table is deep. If, however, the ground-water is a very short distance from the surface, there may be a profuse efflorescence under the usual conditions of dryness of the atmosphere and heat. The second cause of removal is copious rainfall. If the rainfall is copious, it may wash away part of the salts, and this is one of the reasons that in rainy regions alkali is rare. If it is slight and only moistens the soil without scouring it, there will be a continuous production and accumulation on the surface, except when the soil is porous and allows it to be carried down to the ground-water. The third means of removal is by vegetation, which annually takes up its necessary portion of salts and assimilates them. It is frequently observed that in cultivated spots the reh is kept under, while the uncultivated ground around may be covered with it. In connection with this, it is to be remarked that for land plants potash salts are necessary, but it is doubted whether soda salts are essential, except in the case of Salsolæ, &c., which grow in soda soils. This may have something to say to the barrenness of our soda reh soils. Another factor to be noticed is the effect of shade produced by vegetation, which prevents the excessive evaporation which brings the salt to the surface. It thus remains more diffused

through the moisture in the soil. Lastly, plants also induce capillary currents towards themselves. The absorbing parts are the rootlets and myriads of hairs surrounding each. These, by the act of absorption, set up capillary currents in the moisture of the soil towards themselves, which compete with capillary evaporation at the surface and tend to the diffusion of the moisture and its salts through the soil as far as the roots extend. It is to be noted that if a soil remain damp, so that the salts are diffused through it, they may do no harm. It is their concentration as a scum on the surface that poisons crops. The moisture round the rootlets forms a solution so saline that the osmose currents by which the plants are nourished are interfered with and they perish.

27. A very important point materially affecting the question of the cure of reh, is how far reclamation or non-development may be due to diffusion of the salt in the soil. In rainy and damp portions of the plains similar in conditions of subsoil drainage to reh-stricken tracts, we find no efflorescence. How far is this due to surface washing and how far to diffusion? From three experiments made this year, it was found that the rain waters coming off the surface of reh-ground contained a perceptible quantity of the salts. Nevertheless the great fact of occlusion by means of the first soakage portion of the rainfall was proved by the occurrence of a copious efflorescence on the drying of the washed soil. If the rainfall were very copious, would it succeed in washing off excess of salt? This question might be settled by analysis of the total quantities of soluble salt in soils of the rainy and dry tracts of the plains, within the range of surface soakage. As it would be impossible to select two spots precisely similar in conditions of subsoil drainage and constitution of soil, it is evident that no conclusion would be of value except from a great number of experiments.

28. Speaking broadly, the development of efflorescences occurs in India, chiefly in a well-marked meteorological area, including the Punjab, except at the base of the hills, similarly the upper part of the North-Western Provinces, and also Sinde and Rajputana. This region is characterised by small rainfall, dryness of the air, and excessive solar heat, each of these as shown contribute to the concentration of salt on the surface. On the other hand, in similar parts of the Indo-Gangetic plain, where there is more copious rainfall, this of itself by keeping the soil moister causes diffusion of any salt present through the soil. Again, the sheet of air which covers the ground contains more moisture and acts in two ways in preventing surface concentration. It diminishes the effect of solar heat, because, as Tyndall has shown, the invisible vapour of water absorbs a great deal of the heat, thus preventing damp regions, such as Lower Bengal, from reaching such high temperatures as the dry regions of Upper India, even though the latter are of higher latitude. In addition, there is more cloud in the damp regions which also abstracts solar radiation, whereas in Upper India the sky is cloudless most of the year. Again, the presence of a moister sheet of air over the ground abstracts evaporation, which takes place in proportion to the dryness of the air. It is very desirable that a series of experiments should be made regarding the total salts occluded in the drier and moister parts of the plains within the ranges of surface soakage and evaporation.

29. As regards the effect of reclamation, further experiments are also required, in order to show how much is due to removal or diffusion of the salts. I estimated the total salt in reclaimed soil and in adjoining reh-ground to the depth of 3 feet at two places near Lahore. Equal columns of earth were taken up by boring with a tube. The result was negative, as in one case the reclaimed soil contained a little less salt than the adjoining reh-ground, and in the others rather more than a third less. No conclusion of any value can be drawn except from a large number of estimates, the variables affecting each case being also taken into account.

30. The state of porosity of the soil has also a great deal to do with the appearance of the efflorescence. Nothing is apparently more capricious than the way it shows itself in one spot of a field and not in another. This may be partly due to difference of constitution of the elements of the soil, but there is no doubt that another cause must be the facility of capillary evaporation due to the variable mixtures of sand and clay of which these alluvial soils are composed. This also suggests a question that might be of importance, as to how far reh soils could be improved by additions of sand or clay so as to affect their capillary action.

Methods of cure.

31. I conclude this paper with some practical remarks regarding the methods of dealing with saline efflorescence agriculturally; but these I wish to be considered suggestive more than any thing else, as I cannot pretend to any experience in that line. When visiting Utah I was very much struck on finding that the saline efflorescences of that basin were similar in nature to those I had seen and studied in India. I made enquiries into the ideas current on the subject and the methods of reclaiming the soils. Brigham Young's notions of natural philosophy were both extremely simple and at the same time shrewd, as would be expected from an uneducated, but practical and successful man. He said: "There is salt in every thing. Water has salt, plants have salt, and earth has salt; and the Bible tells us that if the earth have lost its salt it is useless. A certain quantity of salt is necessary for vegetation; in our country we have too much of it, and we get rid of part of it." He referred me to Mr. Woodruff, who was Secretary to the Agricultural Society, and to some of the best farmers, to see what was done. The plans adopted were the following: A salt field was ploughed and small runlets of fresh water were sent down the field, at short distances apart, washing the soil and running off into the drainage of the country. Another method was to plough up a field and make a terrace round it and then flood it. The water was allowed to soak for some time till it had dissolved the salt and was then run off. Another plan was to terrace a ploughed field and dig a deep trench round it. The field was flooded, and the unploughed subsoil being less permeable, the water holding the salt in solution filtered into the trench. I observed similar processes carried out on the salt marshes round the Bay of San Francisco. This is gradually silting up, and surrounding it are miles of low flats impregnated with sea salt and growing only saline plants. Through these pass shallow delta channels, scoured by the rise and fall of the tide. To reclaim this soil, low earth embankments are raised

By sluicing and irrigation.

round the farms. These are fitted with flood-gates closed by the rise of the tide and opening on its fall. The salt in the soil is washed out by the fresh water of the streams falling into the bay by a process of sluicing such as I have described, and is run off as the tide falls. In the depression between the coast range and the second range of hills artesian wells can be made, and these were used where none of the mountain streams were available. An English Company was working on a salt marsh by the aid of artesian water only; but it was generally considered that it would not be a success, as the amount of artesian water was after all only trifling compared with the area to be reclaimed. The universal opinion in Utah was, that if they once succeeded in covering an alkali field with a crop of any kind, the victory was won. After the land was half cured, they generally covered it with a hardy grass, the most approved being red-top American grass. Beetroot was also said to grow well as an early crop; after that Indian-corn, and other crops by degrees. Tuberous crops grow well in the country, and the potatoes are said to be the best in the world. The last method I shall mention was that employed by Brother Fenton, an energetic Devonshire farmer. It happened to be impossible for him to get fresh water to wash the salt out of his fields, and he tried large quantities of manure—20 to 50 tons per acre. Barn-yard manure was considered the best, and as his great object was to keep the surface from the sun, which drew up the salt, he also used litter to cover it. The first crops he covered the ground with were the red-top grass and oats, and he sowed his crops in September, so that the ground should be covered with vegetation when the alkali would be appearing. As soon as by this means he got his first crop of red Timothy grass, he found he had succeeded. Mr. Fenton complained that after partly curing one field he ruined it by trenching and bringing up a saline subsoil. His idea was that the salt was a sort of perspiration of the earth, and, therefore, mostly on the surface, and that by turning up the subsoil he would get a better soil. In India it is certainly the case that a short distance below the surface less reh is found. It may be different in a closed basin like that of Utah, where the subsoil also may become saturated with salt. Utah city is partly situated on a bench at the base of the Wasatch hills adjoining the plain, and at first the farms surrounding it were made on the ground that was not saline. About one-fourth of the land under cultivation was salt, and three-fourths of this had been cured by sheer cultivation, much in the way I have described in the case of Mr. Fenton's farm. For the other fourth, sluicing and irrigation had been available. The cultivation of saline soils is also carried out in other settlements. In most old-settled countries, and especially in India, agriculturists are very conservative in following the practices of their forefathers. In America, where the population is composed of emigrants from all countries, every man brings the methods used in his own, and all sorts of trials are made and the fittest survives. These are made in a new country under new circumstances, and people are not bound by traditional customs, but are anxious to try whatever succeeds in the hands of others, and also make experiments according to their own ideas. These may be crude, but still a vast number of experiments

By manure and cultivation.

are made,—not isolated ones by a Government, but everywhere generally by the people themselves—and anything that is successful is hailed as a discovery. Some of the methods I have described as used in America may not always be practicable in the plains of India. To run off the saline water requires a slope and lines of natural drainage that may not be available. It might be possible to run off the salt-impregnated water into absorption wells, thus returning the salt to its natural destination, the underground water. It is a law that a well will absorb as much water without raising its level as it would give out without sensibly lowering it. This means has been used in some cases to get rid of liquid sewage, but was found to poison the wells. The plantation of trees is also proved to be a very efficient means of cure. The kikar is well known as capable of flourishing in such soils. They not only assist in moderating excessive evaporation by shade, but they also absorb and remove a certain amount of salt from the soil. As the alkali exists chiefly in the surface soil and in much less amount at a small depth, trees may grow readily where annual crops could not. The latter have their rootlets only in the surface soil, and are poisoned by the excess of salt; while the roots of trees extend deeper into less saline ground; also plants not only consume a portion of the salt, but they prevent its concentration on the surface. A most conclusive experiment made near the Western Jumna Canal by the Irrigation Department is reported by Colonel Fulton. A piece of utterly useless reh land, for which revenue was remitted, was taken up by the Department and planted with kikar trees. These flourished and a very fine crop of doab grass, 2 feet high, came annually up under the trees, and the efflorescence disappeared. The villagers, seeing that the land was improved and fearing it would be alienated by the new settlement, applied for the restoration of both trees and land, and carried their point in the courts of law. A few days after the restoration the wood was sold to a wood merchant and every tree cut down. At present the doab grass is all gone, and the soil is encrusted with salt. Such an experiment made among American farmers would have excited the keenest interest and given rise to numerous trials of the same.

By arboriculture.

32. The method of cure by nitrate of lime as a manure, suggestad by Dr. Brown, would act in two ways. It would partly serve as a manure favouring vegetation, and in addition it would act on the alkaline and magnesian sulphate by double decomposition, producing nitrate of alkali and sulphate of lime, which last is a slightly soluble salt which is not hurtful to vegetation and would not form an efflorescence. Carbonate of soda would be similarly neutralised, but the sodium chloride would remain unaltered. The natives are well acquainted with this use of nitrous efflorescence, which can be distinguished from the sulphate of soda by its moistness due to deliquescence and by the brown colour and by not efflorescing in fine powder. It consists mainly of common salt and nitrates of lime and soda. This production of nitrate is due to the decomposition of nitrogenous animal or vegetable matter, first producing ammonia, which is afterwards oxidised to nitric acid. An essential condition of the nitrification process is the presence of alkaline carbonate, or carbonate of lime, to fix the nitric acid. For example,

Chemical manure.

ordinary dung heaps may produce plentiful supplies of ammonia, but no nitric acid. Indeed, nitric acid, if present, is changed by the reducing action of the decomposing organic matter to ammonia. If wood ashes containing carbonate of potash or lime be mixed with the heap, the acid becomes fixed. Artificial nitre beds, called *nitrières*, or nitre plantations, were first introduced by the chemists of France to supply nitre for gunpowder during the wars of the Revolution, when the ports of France were blockaded by the English and imports prevented. Animal manure is mixed with carbonate of lime and wood ashes and frequently watered with urine, which produces much ammonia. This is cultivated for two or three years. In tropical countries the production of nitrates is more plentiful and rapid. A manure of a valuable quality could probably be made by municipalities or by the zamindars themselves by mixing pounded kankar, or even marly soil, with manure and moistening it frequently during one or two hot seasons. If it were moistened with liquid sewage, which would tend to produce more ammonia, the production would be increased. This artificial production is an exact imitation of what takes place naturally in soils in which nitre is produced. In the Punjab nitrates effloresce near villages where the soil becomes impregnated with animal sewage, which undergoes nitrification in presence of the carbonate of lime and alkaline carbonate in the soil. The most plentiful supply is in the soil on the mounds that indicate the sites of old villages. This is the main source of the manufacture of saltpetre in the Punjab. Similarly, near buffalo ponds and watering-places for cattle, where dung is trodden into the soil, nitrates effloresce and are swept up by the zamindars as manure. A similar process no doubt takes place when a field is well manured with animal refuse. The conditions of the production of nitrate of lime in the soil are present, and this may account to some extent for the reclamation of alkali soils by manuring alone. For this purpose animal manures would be far superior to vegetable. In plants there is comparatively little nitrogenous matter, which alone can generate nitrates or ammonia. In Utah a favourite manure is the refuse of slaughter-houses, which would be capable of supplying large amounts of ammonia and nitrates.

Uses of reh.

33. As regards the uses to which the alkali efflorescence might be put, sulphate of soda can easily be separated by evaporation and forms a useful purgative. It might be possible to utilize those more rich in alkaline sulphate for the manufacture of carbonate of soda for glass or soap work. The average mixture of sodium chloride and sodium sulphate resembles the product of the first step of manufacture of this carbonate, which is done by the addition of sulphuric acid to common salt. By evaporation the sulphate which crystallizes out first in saturated solutions made from efflorescence containing excess of sulphate, can be freed from most of the common salt, and this would resemble the salt cake. The materials for the further reduction, charcoal and lime, would be readily available, the latter from the kankar beds. Certain soils contain carbonate of soda in such quantities that it can readily be separated by the crystallization process. At one time an enquiry was made as to whether the nitre manufacturers defrauded the revenue to any extent by disposing of the alimentary salt left in the refuse saltpetre earth after

extracting the nitre. Samples have from time to time been forwarded to this office, and these were found to contain from 35 to 70 per cent. of common salt. It would certainly be possible and not very difficult to obtain a rather impure alimentary salt by rough crystallization processes, not only from the saltpetre earth, but also from suitable kinds of reh.

THE REH SOILS OF UPPER INDIA, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

For some time I have intended to publish in the Survey Records a notice of the saline efflorescence known as *reh*, which has been, and will continue indefinitely to be, a subject of the gravest concern to those interested in the welfare of North-Western India. The preceding paper, contributed by Mr. Center, removes the only grounds of hesitation in the matter—as to the adequate illustration of the chemical aspects of the case. The facts of this nature already ascertained by myself and others from the area affected were, indeed, sufficient to establish the case before a jury of experts, and it would have been easy to adduce further illustration from analogous conditions elsewhere; but the men who have to deal with the matter practically are very much the reverse of experts, scarcely even believers, and it is of the greatest importance that the most tangible part of the evidence, the hard facts verifiable by the balance, should be set before them from the very ground which they have to treat. This has been done in a very satisfactory manner by Mr. Center. It only remains for me to supplement his paper regarding some points which it touches on but slightly. The question is truly a geological one, as embracing all the conditions of a complex operation now at work in producing a change in the whole region affected. This has been the difficulty throughout—to induce an apprehension of the situation: that the evil to be encountered is not a fixed obstruction of assignable dimensions and position, but the present active array of natural causes bent upon fulfilling the effects due to conditions that have supervened. In such a case our best efforts may be no more than palliative, unless indirectly, by modifying those conditions, we can mitigate the action of the prime causes.

2. From times far earlier than the date of British occupation, there have been large patches of reh-affected ground in various parts of the Upper Provinces. They are known as *usar* (sterile) and *kalar* (saline) land. As the contention sustained in this and the preceding paper is, that this salt (as such) was not an original constituent of the deposits in which it now occurs, it would be interesting to find any mention of the *usar* lands in remote records of those districts; but it is not at all unlikely that some of them may be of very ancient origin, from the historical point of view. What has recently (within the last 30 years) brought the subject into such prominence was the rapid local extension of reh efflorescence in connection with the great irrigation canals that have been constructed in Upper India. Shortly after my arrival at Roorkee (Rurki), then the head-quarters of irrigation, I was consulted about this plague of salts; not, indeed, as a geologist,

but because I dabbled in chemistry. Samples of soils, sub-soils, and waters were sent for examination. The rough results of this work and of such field observations as I could make in the neighbourhood (which was not a reh district) were brought together in a paper for the Asiatic Society, London (Journal, Vol. XX, p. 326, 1863). This paper and a number of official reports on the same subject were published as No. XLII (1864) of the Selections from the Records of the Government of India in the Public Works Department, as "correspondence relating to the deterioration of lands from the presence in the soil of reh." Many other letters and reports, such as that of the Aligarh Committee in 1878, have from time to time been printed for departmental circulation; but the above is the only information that I know of as available for general reference.

3. So early as 1850, in reply to some questions with samples for analysis, Dr. O'Shaughnessy had supplied facts from which an understanding of the whole case might have been evolved: that the canal water is remarkably pure, although containing an appreciable amount of the reh salts; that the sub-soils of reh land are remarkably free from salts; that the reh is accumulated in the surface soil; and he pointed out that a free use of canal water, with efficient drainage, would certainly cure the evil (*l. c.*, p. 36). No suggestion was, however, made as to how the reh came there: so on this score full play was left for fancy to suit the bias of the speculator. Accordingly, the final decision passed upon these facts by the Board of Revenue is recorded as follows (*l. c.*, p. 8) :—"There is, then, positive scientific evidence that the canal water is perfectly pure, and the idea, though it has been started more than once, cannot be entertained for a moment that the salts are deposited by the water used in irrigation. When *reh* appears, it must be that it has previously existed in the soil. For in no lands is the efflorescence of *reh* so extensive or so rank as in those large spaces so common in all the villages of Panceput and Soonput, where the plough has never been driven; where seed has never been cast; and which, under the name of *kullur* (answering to the *oosur* of the midland districts), were excluded from the malgoozaree area, for the express reason that they were barren, or, in other words, had too much saline matter in their soil to admit of their being cultivated." This judgment gives a fair illustration of a mischief that too often occurs in India; as must happen where the higher administration is in the hands of men who have grown into it, after a long training in a narrow but very real school of virtual omnipotence, resulting in impenetrable self-confidence; and who consequently never hesitate to undertake and pass decisions upon matters where they are quite unqualified to hold an opinion.

4. Finding that in this matter the local fancy was without rational bounds, and the bias strong in a false direction, I set myself (in the paper referred to) to trace the source of the reh; I pointed out (*l. c.*, p. 40) how the supposition of any store of reh in the ground was untenable, except of course when reh-water had lodged in the upper water table; I proved a case (*l. c.*, p. 43) in which a reh soil had been produced by accumulation from a source no more abundant than the canal water; I stated my conviction (*l. c.*, p. 45) that the old *usar* or *kalar* lands were only special areas of inefficient drainage, lands more or less dependent on evaporation for the removal of surface waters; that, in fact, the

whole phenomenon of reh was superficial, due to the inefficient circulation of the atmospheric waters under extreme climatal conditions.

5. The foregoing brief remarks must suffice as a historical summary of the reh question. We may now, perhaps, assume that the rational explanation of the situation is accepted, or must become so; and proceed to form an estimate of its conditions. My remarks here also must be condensed, referring only to the leading features; a fuller discussion of some particulars was given in my reports to the Aligarh Committee of 1878.

6. The only points to which I need take exception in the views set forth in the preceding paper, are those from which it might be inferred that the state of things so much to be deplored—no less, in fact, than the steadily-advancing conversion of the choicest lands of India into a howling wilderness, such as now obtains over the once luxuriant Mesopotamia—that this is inevitable from natural causes. I have pointed out these weak points to Mr. Center, and he has permitted me to explain them, rather than undertake to do it himself:—It is correctly stated that under certain conditions of surface configuration, of ground structure, and of climate, the local accumulation of saline deposits must take place; the instances given are the great land-locked basins of central North America and Asia. The first condition may be ignored, as it is immaterial whether the surplus waters are concentrated in a local basin or added to the briny deep.

7. The second condition is important. In several passages of paras. 14, 21, and 24 of Mr. Center's paper, the strata forming the plains are described as horizontal, so that the conditions of drainage approach those of a basin, the underground drainage being usually imperceptible. These features of the bhángar land are contrasted (para. 24) with those of the khádar land, where "the river occupies the line of natural drainage of the country, and its deposits are parallel to the line of slope," underground drainage taking place freely; and this, although the khádar valley is truly described as cut out by recent erosion from the old alluvial plain. The small apparent contradiction here is easily explained: the ground surface in the khádar is almost always of very recent sandy deposits, the surface of actual erosion being confined to the present river channel; but there is a real and greater misconception which it is needful to insist upon. It is not questioned that the plains themselves are river deposits; their surface, too, lies appreciably parallel to that of the actual river beds throughout; so it is not intelligible how the lie, or the composition of the strata, can be supposed so different from those of the actual rivers. In the process of land formation by rivers, of which the plains of India afford such a striking example, there does occur partially the production of local basins. From the diluvial zone, where the torrents are discharged from the mountains, to the more exclusively alluvial region of the delta, a partial sorting process takes place in the river deposits. The coarser materials, which in the former position are boulders and gravel, and in the latter fine sand, become thrown down wherever the velocity is checked and along the margin of overflow, thus forming the banks between which the river flows, whether in a single channel or through several distributaries, often at a higher level than adjoining ground separating the channels. These intra-fluvial areas become for the time swamps or temporary lakes in

which some deposition of finer sediments occurs more or less in basin fashion; but they principally become filled up by the invasion of the river to find a lower level; when, at least on the line of the new channels, there must be considerable removal and ultimate replacement of any finer sediments. In this way it seems probable that in the growth of the river plains, it is rare for any large area to escape being traversed by a channel of considerable magnitude, or for such areas to be filled up by deposits in which the slope of the river itself is not on the whole maintained. The original *usar* plains may have been such exceptional areas, in which therefore special local obstruction existed to underground drainage. It must, indeed, be admitted that the actual subsoil drainage of the plains is usually imperceptible; but this seems to be directly accounted for by what is the head and front of the complaint regarding reh: that owing to shallow cultivation, to the sun-baked condition of the surface, and to the absence of any considerable tree vegetation, the rainfall can only soak to a small depth, the remainder running to waste off the surface, or being taken up again by evaporation. For efficient drainage there must be efficient penetration to supply it withal: and, deficient percolation of water through the soil and the sub-soil to the ground beneath is the condition, in default of which the growth of reh is inevitable. It would, of course, be easy to imagine circumstances more favourable to drainage than are those of the gently-sloping alluvial deposits of these plains; but it seems to me that reh being in part a necessity of the ground structure here, cannot be sustained.

8. There remains the condition of climate, which is the active element of the combination. It is represented (para. 15) as being analogous to that of the typical cases cited, only intensified by heat. Here, again, I have to admit the actuality, but as a charge against nature it is even more untenable than the last. There is contrast rather than correspondence between the physical surroundings of India and those of the typically arid tracts mentioned. In these, aridity is indeed more or less inevitable, for the life-giving moisture hardly approaches them, being to a great extent abstracted from the air currents before they reach these areas. But India is on two sides bounded by a reeking caldron of tropical ocean; and on the third there is a great air-elevator, flanked by a huge condenser, sending back upon her plains almost every drop of the water that had previously floated over them, repelled to a very large extent by the accumulated heat of the bare and parched ground surface. The endeavour to make these returning waters do duty for rainfall must be a very poor substitute for the due reception and conservation of them in this form in the first instance. It can scarcely be questioned, that left to nature, every foot of our Indian deserts would now have been covered with perennial verdure, and that the present desolation is the result of the devastating proclivities of a worse than savage mankind. It may, too, be affirmed that with time the blessings of nature might be restored.

## NOTE ON THE NAINI TAL LANDSLIP (18TH SEPTEMBER 1880), *by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

On Saturday, the 18th of September, at half past one in the afternoon, after more than thirty-six hours of heavy continuous rain, a portion of the hill forming the north-east slope of the valley of Naini Tal fell, sweeping away several houses, and causing the death of 43 Europeans and more than 150 Natives.

Briefly told, the story of the slip is this: On the morning of the 18th, at ten o'clock, a small slip occurred behind the Victoria Hotel, burying part of the buildings in which were some Natives and an European child. A party of volunteers and a working-party from the depôt were soon on the spot, but after a while the greater portion of the latter were withdrawn. After rescuing all that there seemed any probability were still alive, they found that the house was in danger of being washed away by a stream of water, and so turned their attention to the diversion of the stream; and while engaged in this, the great slip came down and overwhelmed them. It is possible that the wash of this diverted stream may have directly contributed to bringing down the landslip, but it seems to me very improbable that it had any such effect; at most it can but have hastened the catastrophe by a few hours.

The part of the hill which has fallen extends up to the old Government House, marked as such on the map. From here the western boundary runs down a little to the east of Marshal Cottage and Charlton; the eastern boundary passes down just to the east of the Victoria Hotel. The mass of debris which has fallen from the hill extends over the level ground at the head of the lake, as far as the Assembly Rooms, of which but the southern end remains standing.

The slip, as it at present stands, stretches in a long, gentle slope, which, omitting irregularities of surface, is not more than 15° up to where the old Victoria Hotel stood; from there it rises in a steep slope of 25° or so, and at the top comes a short space nearly vertical. This steep slope is formed by the small slopes of drier debris which fell after the great one. The total length of the slip, measured horizontally, is about 600 yards, of which over 300 are occupied by the gentle slope, and the remainder are more or less steep.

The hill on the north-east of the lake consists of more or less imperfectly-cleaved clay slates, occasionally showing signs of an initial metamorphism into schist, but for the most part a simple clay slate. The dip is very disturbed, and varies much in different parts in close proximity to each other; but the general dip is to the south-west. The rock also is traversed by very numerous joint planes, which cause it to split up into innumerable fragments under the action of the weather.

Although the whole of the ridge bounding the Naini Tal valley on the north-east is practically one as regards its internal structure, yet, superficially, the south-east portion is very different from the north-west. Looking from the head of the lake, or, still better, from near the old Government House, one cannot fail to be struck by the difference of profile; towards the lower end of the lake the hill sweeps down at an even slope of about 25° from almost the top down to the level of the lake, while nearer the spot where the landslip took place there is a peculiar

bulged appearance of the hill, which makes the slope steeper near the bottom than it is higher up, being occasionally, as above the mission premises, as steep as 35°.

These two areas can be recognised on the map; the even slope near the lower end of the lake is drained by innumerable channels running almost straight down the hill, while on the bulged portion the streams are fewer and their courses not nearly so directly down the hill.

The cause of this bulged appearance I take to be as follows: By the action of the weather the face of the hill gets covered with a greater or less thickness of decomposed rock, which, as already explained, weathers into a mass of small fragments. The rain water, which obtains access to the interior of the hill, for the most part keeps in this decomposed layer and flows down at a short distance from the surface, passing out again lower down in the springs which exist in numbers over this hill, and a large part doubtless percolating downwards reaches the lake without coming to the surface. The presence of large quantities of water among this decomposed rock must, by making it more mobile, assist in producing that phenomenon which is seen in any mass of debris lying at a slope, whether it be wet or dry, namely, the gradual passage of such debris down the slope under the influence of gravity; that some movement of the debris down the slope takes place after heavy rains, seems certain, as is shown by cracks appearing in the surface of the hill side, the lower side of which subsides slightly. Now on a level surface the action of gravity can have no effect in producing any motion, while on a slope the force tending to produce such motion varies directly as the resultant of the vertical force of gravity acting directly down the slope, that is, it varies as the sine of the angle of inclination. Suppose, then, an even slope passing near its base into level ground, and that slope covered with debris; the debris slides slowly down the hill, but on the steeper parts of the slope it must do so faster than near the bottom, where the slope is less and there is the resistance of the debris lying on the level to be overcome, which can only be done by a *vis a tergo*, an impulse from behind. The debris coming slowly down from above and meeting with this obstacle gradually accumulates till it causes a bulging of the slope towards its base, which goes on increasing till the lower part of the hill is so steep that, to use a colloquial phrase, "it is touch and go" whether the hill can stand or not; then a burst of rain heavier than usual comes, the head of water is increased, the force of the water flowing out near the bottom is increased, it begins to wash away the debris near the bottom till the support being removed from below small slips begin to fall; then a few larger, and finally comes the great slip, which brings down the outer crust of half the hill side, leaving a precipitous border round that part from which it has come; finally, the great slip is followed by smaller ones, which leave the hill with a pretty uniform slope from top to bottom for the whole process to begin again. Such I believe to be the history of one of these landslips where there is no stream cutting at the base of the hill; where that is the case, slips may be formed at any time by the cutting away of the foot of the slope.

The slip under consideration has followed very much the course pointed out; the bulging had reached the critical point: all through last rains small slips

occurred; on the 18th a larger one fell, shortly to be followed by the great landslip, which was itself followed by one or two minor ones, though the process of smoothing down the slope has not yet been completed.

Applying this hypothesis to the determination of the question of how much of this same ridge must be pronounced as unsafe and liable to slippage, we must condemn the hill side from a line running upwards from the bank-house to a similar line running down from a little to west of Fairlight Hall, it being all more or less bulged; of this, that part extending from the old landslip to the stream flowing down to the east of the Mission premises must fall in a few more years, but, with this exception, a judicious system of revetment of the torrent beds and a complete system of drainage of the cleared sites will do much to prolong the existence of the present hill side.

As regards the slopes below Chína, there is but little chance of such a slip taking place; these slopes are the talus of the steep scarp of Chína, and are continually receiving additions from above, and though on them there may be danger from the large boulders which occasionally fall from Chína, the slopes pass off so gently into the comparatively level ground at the head of the lake, and are moreover concave rather than convex in profile, that I consider the probability of any of them forming a large slip to be very small indeed.

Many interesting points might doubtless be elicited as to the manner in which the mass moved, were there any satisfactory accounts of eye-witnesses; but such there are not, and for the same reason that it is almost impossible to get a trustworthy account of a great earthquake,—the thing is so sudden and so awful that none but trained observers can keep their presence of mind necessary for making those exact observations which only can be of any scientific use.

The only points which can be satisfactorily established are, that the whole fall must have been over in less than quarter of a minute, and that the Victoria Hotel and Bell's Shop (Racquet Court) were carried along some distance before they fell; in the latter case there is proof of the fact, inasmuch as the ruins are now some yards from the spot on which the building originally stood. As the ground on which both these buildings stood consisted entirely of debris, locally known as 'shale,' which must have been saturated with water after the heavy rains which for thirty hours and more had been pouring into it, it is not surprising that when the wreck of the hill side was precipitated on to it, it should yield as a semi-fluid body would do and float the buildings for some little distance before the actual slip overtook and overwhelmed them. That the whole mass must have been in a semi-fluid state from the amount of water contained in its substance, is shown by the low angle at which it now lies, and by the fact that those who ventured on to the fallen mass immediately after its fall sank up to their knees in the slush, as it has been described.

Doubtless, the point of most scientific interest in connection with this landslip is its bearing on the theory of lake formation by landslips. One of the principal objections raised to the supposition that the barrier at the outlet of Naini Tal, for instance, can be formed by a landslip is, that those slips "possessed of most mobility, from the greater fluidity of their composition, are in the

precise ratio of such fluidity least capable of * * bearing upon their surface craggy masses of rock, such as I should term erratics" (*supra*, p. 165). The examination of the landslip under consideration disposes of this objection; for though most certainly such 'craggy masses of rock' were not born on the surface of the semi-liquid mass, yet there were numbers such floated in its substance, many of which now show at the surface, several being 9 or 10 feet in length exposed; and I have no hesitation in saying that were this landslip on a larger scale—for it must not be forgotten that compared with several others in the hills around it is insignificant in size—and left untouched by the hand of man, it would, when cut into by rain and streams, show many if not all those features which are supposed to be especially characteristic of a moraine.

As to the question whether the barrier of the Naini Tal basin is a landslip or a moraine, I shall not here enter into its discussion; this, however, I must say, that the profile of the slope to the east of the outlet bears every appearance indicative of a large landslip having fallen there. On the hill side there is no bulging, but a straight sweep down to a comparatively level terrace, through which the stream forming the outlet of the lake has cut down for some distance. Whether the lake was formed by the landslip, or whether this was subsequent to the formation of the lake, I am not prepared to assert dogmatically; but this I believe, that in past times there has been a great landslip from the slopes of the Kalikhan, and that on this old slip are placed the hospital and convalescent depôt.

The recent slip shows clearly that a large landslip can extend across and fill up a valley, and at the same time may show that mixture of rocks of all sizes which forms one of the chief features of a moraine; and it is not improbable that, under favourable circumstances, it might resist the wash of a stream over it and so form a permanent lake. In the case of Mulwa Tal, one would certainly suppose from the look of the ground that if its existence is not due to a landslip, yet the level of the water must at one time have been raised some twenty or thirty feet higher than it now stands, by a great landslip which has undoubtedly fallen from the hills to the east of the outlet in times which may not date further back than one or two hundred years, and are certainly later than much that geologists would speak of as recent.

But if a lake is to be formed by a landslip, it must not merely be one of those which are everywhere to be seen, caused by the cuttings of a stream into the base of the slope, but rather one of those which take many years and even centuries preparing, as has been the case with this small one at Naini Tal, and which when they fall do not come down in a stream of fragments, but with one great rush, which would carry them right across the valley and raise the surface to such a height that, by the time the dammed-up water reached high enough to overflow, the debris would have had time for the water mixed with it to drain off somewhat, and would have settled down sufficiently to withstand the wash of the stream running over it. Such cases have been known, but the dam has always given way; yet it is not inconceivable that in some cases which have happened in that remote past, of which we have no knowledge but what is written in the rocks, some few barriers so made were able to stand and form what are now known as the Kumaun lakes.

Yet it must always be kept in mind that no theory which can be put forward to account for their formation can be considered satisfactory, unless it also accounts for the absence of similar lakes in other parts of the Himalayas; for it is no explanation to say that this is due to the smallness of the drainage areas which supply the lakes, and the consequent small size of the streams flowing from them, for other portions of the Himalaya are not devoid of small streams, nor can that which flows from Mulwa Tal be called small.

## NOTE.

My youngest colleague, Mr. Richard D. Oldham, happening to be in Kumaun at the time, I asked him to give me an account of the disastrous landslip at Naini Tal. The foregoing excellent paper is the result. It is Mr. Oldham's first contribution to the publications of the Survey; and the accurate observation, strict reasoning, and good form it evinces, give high promise of fruitful work to come.

It will not be amiss, on an occasion of such vital interest, to add a few remarks that occur to me, especially as suggested by the report of the Committee appointed by the Local Government to enquire into the condition of the Sherka-danda hill, a copy of which was sent to me officially at about the same time, 'for information.' The portion of the hill marked by the Committee as presently dangerous corresponds very nearly with that indicated by Mr. Oldham; but their observations would seem to have a wider extension, and to involve a larger area of affected ground. Mr. Oldham was only there for a few days, on his way to take up work for the season in Sirmur, and he probably confined his attention to the particulars of the event under discussion. I did not instruct, or expect, him to do more than he has done, the Survey not having been called upon for an examination of the ground.

It would be understood from the report of the Committee that the surface cracks, justly regarded as symptomatic of failing ground, occur much beyond the area condemned, also the Committee's description of the geological structure of the hill would be taken in the same sense; it is as follows:—"To the ordinary observer the hill seems to consist of a core of rocky shale, the dip of the strata being to the south-west, at an angle varying from 30° to 50°. This core is covered by varying thicknesses of disintegrated shale and mud, in which are scattered boulders of limestone, and occasionally of trap, the whole of this crust being in its natural state bound together by a luxuriant growth of grasses, shrubs, and trees." It does not appear that this is thought an unusual composition for the crest of a steep ridge, 7,000 feet in elevation. As applied to the dangerous ground, it would exactly suit the conditions described by Mr. Oldham—the decomposed clay-slate creeping down the hill side, carrying with it blocks detached from the occasional outcrops of harder rocks. It is scarcely possible under the circumstances that such a crust could be rock *in situ*, whether an enveloping shell of some unconformable deposit, or a condition, however decomposed, of the rocks described as the 'core.' It can, in such a position, only have been formed from these latter by displacement, being either the remains of an old landslip, or the material in order of active preparation for a slip to come. In the former case the ground may be perfectly safe, in the latter it would be at least doubtful. If, then, this description applies extensively, as might be inferred from the Committee's report, the matter may be worth further consideration; for the premonitory 'bulging,' so effectively detected and described by Mr. Oldham, may not be a necessary part of the performance. In the case of the condemned area, that feature is reasonably ascribed to the resistance so well presented at the base, where the slope tails off into the flat ground at the head of the lake; but where this condition does not obtain, as along the lake shore to the south-east, a crisis might occur without that visible warning, although there would be every reason to expect it to be mild in comparison to what happens when an accumulation has occurred by bulging.

Altogether, it is by no means unreasonable to hope that the practical judgment of the Com-

mittee may be well founded—that, except in the proscribed ground, security can be insured by proper precautionary measures. Mr. Oldham has expressed the same opinion.

In the 30th September number of *Nature, a-propos* of the Naini Tal catastrophe, there is a picturesque description of landslips in general. The writer is evidently thoroughly informed upon the subject he treats of, although grievously in error regarding the geological condition of Naini Tal, which is described as on the tertiary rocks. This mistake is unaccountable; for the place is clearly shown on our geological sketch-map of India as inside the Sub-Himalayan boundary. From the foregoing notice it will be plain that the Naini Tal slip cannot be classed with any of the particular cases mentioned in *Nature.* I have seen no fact to suggest that there is any predisposing plane of stratification connected with these slips. The contrary may, indeed, be affirmed; for although the general dip of the strata is stated to be south-westerly, the frequent contortion these slates have undergone almost forbids the supposition of a continuous surface of any extent in a fixed direction, such as is implied by the action in question.

The Naini Tal landslip of the 18th September was in fact, except on the score of mischief, a comparatively small affair, considerably less in magnitude, as mentioned in Mr. Oldham's paper than several others that occurred at the same time in the Kumaun hills.

H. B. MEDLICOTT.

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